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The Milroy Lectures

ON

THE ETIOLOGY OF TYPHOID FEVER AND ITS PREVENTION.

LECTURE I.

Delivered on Feb. 20th, 1902.

MR. PRESIDENT AND GENTLEMEN,—When the Council of the College paid me the unusual compliment of requesting me to deliver the Milroy Lectures this year I felt that although my time was more than fully occupied I could not refuse the honour so graciously offered me and I therefore accepted the duty without hesitation. Had I, however, known that I should have to go through a serious illness towards the end of last year—an illness from which I have not yet fully recovered—I should certainly have shrunk from the ordeal. I have chosen the subject of typhoid fever partly because it has not been treated before in these lectures (although Dr. P. Horton-Smith delivered his Goulstonian Lectures on the Typhoid Bacillus in 1890), and partly because I have had an unusual experience of that disease from many points of view. I studied it under William Jenner—of whose part in elucidating it I shall have something to say further on—35 years ago. Soon after that I worked through a severe outbreak of it while prosecuting my post-graduate studies as Radcliffe Travelling Fellow of the University of Oxford at Lyons—an epidemic which filled all the medical wards and half-filled all the surgical wards in the hospitals of that city with cases of typhoid fever of every variety. Since then much of my time has been occupied in investigating both large and small outbreaks of the disease, in studying the conditions under which it spreads and the means of preventing it, whether in the form of widespread outbreaks or of cases in households. During these investigations I have, of course, been exposed to the infection of the disease on very numerous occasions, of which I may especially allude to one where I traced a severe outbreak in a small country town to the contaminated water of the well at the hotel in which I was staying. I attribute my immunity during all these numerous exposures to the fact that I well remember suffering when a boy from what was called "brain fever." The first medical paper I wrote was entitled "On the Alleged Spontaneous Origin of the Poison of Enteric Fever." It was read before the Epidemiological Society of London in March, 1874, and will be alluded to at length further on.

I have used the name "typhoid" in the title of these lectures in preference to "enteric" fever, as it is the oldest name now in use—the name which Jenner used and of which Louis says, "it is almost free from objection," and also a better name than "enteric," as it expresses the fact that it is a disease which resembles typhus fever—a fact which cannot be gainsaid, as it was confused with it by most physicians up to near the middle of the last century. "Typhoid" is also a better name than "enteric" for a general disease, for we do not call other fevers by names merely denoting the organs in which their most specific lesions occur. As Dr. Charles Murchison says: "It would not be desirable to have any name derived from the abdominal lesion, tending, as this would do, to revive in the minds of many the exploded doctrines of Broussais"—viz., that the fever was caused by the intestinal inflammation. I may also add that the name of the organism now identified with the disease is "bacillus typhosus" and not bacillus entericus or enteritidis.

The historical part of the subject has been so fully treated by Dr. Murchison, who has given us a summary of the history of typhoid fever from the time of Hippocrates onwards, that it is quite unnecessary for me to go into the early part of it in any detail. I think it desirable, however, that I should go at some length into the question of the knowledge of this disease at the beginning of the last century, and of the development of such knowledge since, by giving an account in some detail, and as far as possible in the words of the authors themselves, of the most important works on the subject since the early part of the last century—works which have really advanced our knowledge, written by great masters, the medical giants of their day.

In the first place I wish to introduce to your notice a hitherto unknown author, a copy of whose work I have found in the library of the Royal Medical and Chirurgical Society. I refer to him as an unknown author because his work is not referred to by Dr. Murchison, although he cites a great number of authors both on typhus and typhoid fever, nor, so far as I can find, is it referred to by any other writer. There is no copy of this work in the library of our College or in that of the Medical Society of London, or even in that of the British Museum. The copy that I found in the library of the Royal Medical and Chirurgical Society has been there for many years, but has been read by no one, as its leaves had not been separated when I found it. It is written in Latin and is entitled, "Specimen Practicum de Remediis Efficacissimis in Morbis Contagiosis ac Pestilentialibus adnexa Commentatione de Contagiis et Febribus Typhodeis." It was written by Christopher Mayr, Doctor of Medicine, "olim Variorum Nosocomiorum Medico Secundario, ac Quondam S.S. Caes. Reg. Apost. Maj. Status Militaris Medico Supremo, et Magni Nosocomii Militaris Vindobonensis Medico Primario. Collegii Medici Vindobonensis Sodali," and was published in Vienna in the year 1806. In this treatise fevers are divided into eight classes or genera (see Table I.).

TABLE I.

Conspectus Febrium.—Febres Principes Elementares seu Cardinales

I.

Synochus imputris, seu Febris Continua non putris.
1. Febris inflammatoria.
2. Febris biliosa.
3. Febris pituitosa.

II.

Synochus putris utplurimum Malignus, seu Febris continua putrida utplurimum maligna.
Typhus. Quinque species Typhorum.

III.

Febris intermittens.

IV.

Febres continuæ remittentes seu compositæ
et
Febris ardens seu καυσος.

V.

Febres epidemicæ intercurrentes.
Variolæ.
Morbilli.
Scarlatina.

VI.

Febris indeterminata, nova, incognita.

VII.

Febres Sporadicæ et Singulares.
Febris lactea.
Febris puerperalis.

VIII.

Febris lenta, hectica.
Phthysis pulmonalis.

The five species of typhus under Genus II. are shown in Table II., as follows:—

TABLE II.

Quinque Species Typhorum.

Primo. *Typhus verus pestilens contagiosus seu Pestis orientalis.*

Secundo. *Typhus verus gangraenosus, contagiosus, icterodes, pestilens,* vocatur etiam *Pestis occidentalis,* seu *Febris pestilens, contagiosa, epidemica flava americana.*

Tertio. *Typhus verus non contagiosus putrido-biliosus seu bilioso-putridus,* seu *Febris putrida sanguinea* seu *putrida saburralis.*

Quarto. *Typhus verus nervosus seu pituitosus non contagiosus,* seu febris nervosa, seu febris lenta nervosa anglorum, vel febris putrida pituitosa a pituita acri et putrescente ortus, *tarde decurrens.*

Quinto. *Typhus Spurius seu fictitius.*

By this most interesting classification of fevers we are able to understand exactly the view taken of them at the beginning of the last century, and from the accurate descriptions given of some of them in Mayr's book we are able also to understand how much was known about them and how far they were distinguished one from another. Each of these eight divisions is considered by Mayr to be a genus and each of the sub-divisions a species—that is to say, a distinct disease and not a mere variety. This is clearly shown by the sub-divisions of Genus V.—viz., small-pox, measles, and scarlet fever—which are obviously distinct diseases. I may at once draw attention to the remarkable fact that he includes pulmonary phthisis among fevers as the only species of Genus VIII., entitled "Febris lenta, hectica." He does not, however, tell us whether he considers phthisis a *contagious* fever or not, but he probably did, as throughout the southern parts of Europe it has always been considered a contagious disease. His first genus is continued fever, of which he considers that there are two species. His second is typhus, of which he describes five species, which he styles "diversae species," as follows :—

"Primo. *Typhus verus pestilens contagiosus seu Pestis orientalis.*" By this he no doubt meant true contagious typhus fever, with which the oriental plague was associated and confused up to that time and later still, for he says further on in his treatise that to the genus called typhus belong "the fever of hospitals, prisons, camps, ships, and many others, as also especially the true Pestis orientalis." He therefore recognised that his first species of typhus was the fever of prisons and other crowded places.

"Secundo. *Typhus verus gangraenosus, contagiosus, icterodes, pestilens,* vocatur etiam *Pestis occidentalis,* seu *Febris pestilens, contagiosa, epidemica flava americana.*" Or true contagious yellow fever.

"Tertio. *Typhus verus non-contagiosus putrido-biliosus* seu *bilioso-putridus,* seu *Febris putrida sanguinea* STOLLII, seu *putrida saburralis* STOLLII qualem sordes putridae e systemate gastrico in sanguinem attractae generare solent. In *putrida sanguinea* vero vitium in systemate sanguineo primario natum ; a colluvie bilis putridae in sanguine seu secundis viis abundantis nata, vel ex primis viis in secundas delata ; vocatur quoque *Typhus mitior,* lentius decurrens, non contagiosus, vel *Febris putrida non contagiosa.*" A perfectly clear and unmistakeable definition of one of the varieties of typhoid fever, of which he further says, so that there cannot be the slightest doubt about the matter : "Haec Species *Typhi* potissimum cum inflammatoria febre aut topicis affectionibus complicata esse solet, cum aut sine exanthematibus ; inde Peripneumoniae malignae, Hepatitides, Dysenteriae et Mesenteritides gravissimae etc. observantur."

"Quarto. *Typhus verus nervosus seu pituitosus non contagiosus,* seu febris nervosa, seu febris lenta nervosa anglorum, vel febris putrida pituitosa Stollii, a pituita acri et putrescente ortus, tarde decurrens." Another well-known variety of typhoid fever of which he remarks: "Haec Species *Typhi* cum inflammatoria et biliosa febre ac topicis affectionibus, cum aut sine exanthematibus permixta et complicata esse solet." And further adds the following shrewd observation which anyone who has had anything to do with the treating of cases of typhoid fever will agree with: "In nullo morborum genere tanta opus est patientia, exspectatione cunctationeque ad bene et feliciter medendum: est enim difficilis hujus morbi Diagnosis et Therapia." Typhoid fever is described as "nervous fever" by Gilchrist, Huxon, and Manningham; as "nerven fieber" by German writers; "fièvre nerveuse" by the French; and "low fever" or "brain fever" by many English writers.

"Quinto. *Typhus spurius seu fictitius*." Apparently equivalent to the *embarras gastrique* of French authors. He says that it is often confused, as might be expected, with the *typhus verus* of the third or fourth species—i.e., with typhoid fever.

These five species of "typhus" Mayr considered to be distinct diseases, but his third, fourth, and probably fifth, were evidently our typhoid fever, in which he thus recognised either two or three diseases; and who shall say even now that he was wrong? It would not be in the least degree surprising if it were definitely proved that under the term "typhoid fever" we now include at any rate two quite distinct diseases. Mayr, therefore, clearly distinguished between typhus and typhoid fevers. He put them down as separate diseases belonging to the same genus, typhus being a contagious fever, and typhoid, including the third, fourth, and fifth species of the genus, being non-contagious. It becomes now exceedingly interesting to ascertain what further differences he points out between the two diseases. He says under the heading, "*Diagnosis Primae et tertiae Speciei Typhi*": "The symptoms of the first and third species of typhus (that is to say, of typhus fever and typhoid fever) are in common and very similar except that in the first species of typhus more bad symptoms appear in the sick than in the third species of typhus, and that in the first species of typhus bubones, anthraces, vibices, are more often observed than in the third species of typhus, and that the first and second species of typhus (i.e., typhus and yellow fever) often prostrate even the most healthy men by contagion contracted, which does not happen in the third non-contagious species, but (in which) the prodromata precede a long time before the disease breaks out; and that in the first and second species of typhus on account of their contagious nature the mortality is far greater than in the third and fourth non-contagious species of typhus." Under the heading, "*Causæ harum febrium*," Mayr says: "Besides contagion, which affects different people in various ways, there is also a pestilential contagious *poison* which is transferred and communicated to others in the *first species of typhus* from the infection of one suffering in a similar way; as in the typhus of the first species, so also in the *non-contagious typhus* of the third species it supplies the cause, it deprives of all the force of life, it depraves the humours, it relaxes the system." He then gives a number of predisposing causes, among which are warm and moist air, the close atmosphere of ships, hospitals, vaults, camps, crowded cities, &c. Air contaminated with the effluvia of pools, of animals, and vegetables, especially of putrid things, &c. It will be noticed that he mentions overcrowding first and that he no doubt refers to as the cause of true typhus fever. He then goes on to putrid substances, but it is too much to conclude from this that he therefore understood that these were the causes of the third, fourth, and fifth species of his genus of typhus—that is to say, of typhoid fever. Further on in his book he refers again to contagion at some length in a chapter entitled *De Contagiis*, towards the end of which chapter he says: "It is, moreover, to be noted that certainly not all the typhode contagions are of so volatile a nature that they are always and absolutely spread abroad and volatilised in the atmosphere, and therefore (other things being equal) can act only in true epidemic fashion, but that many of them, and some of the most virulent and malignant, as long at least as a strong degree of heat does not act upon them, show a sufficiently fixed character and remain fixed for a longer or shorter time upon various other bodies which catch them—viz., upon different goods, especially those of wool and cotton, of silk, of leather, feathers, flax, or the hairy skins of animals, clothing, paper, wood, beds, walls, and buildings, and often after many months they break out from these hiding-places still in full force, they infect the atmosphere, and propagate disease and death far and wide."

I must now direct your attention to another remarkable treatise, the work of J. Val de Hildenbrand, Professor of Practical Medicine at the University of Vienna, which was published there in 1810, and a translation of which was published in Paris in 1811. In this treatise the author maintains that the word "typhus" has been improperly employed to designate a *genus* of disease, and that it ought to be used as the name of a particular *species*. He says that the true typhus has often been mistaken for another fever, just as certain other fevers have been mistaken for typhus. "But," he says, "in order to avoid all further dispute about the name of a disease of which the primitive meaning has been lost by an abuse of language, I declare that I treat in this work of the true *contagious typhus* alone, which develops in the human body its special poison by means of which it afterwards spreads, which is everywhere and always perfectly like itself, and of the same essential nature, because it proceeds from a poison *sui generis* and always the same, which disease in fine ought alone to bear the name of typhus because it possesses the special characters expressed by that word. Contagious typhus is an essential fever the course of which displays a constant uniformity. It is a fever of a *special species*—as small-pox, for example. It is contagious because by means of a special substance which develops during the disease it is transmitted and communicated to those who are predisposed to it. By reason of an eruption which is peculiar to it it belongs to the family of the exanthematic fevers, among which the contagious fevers ordinarily find their place. It has a course determined in measured periods and also different characters in its different periods, but with a constant symptom throughout the whole course of the disease, which is stupor with delirium or 'typhomania.'" And he goes on to distinguish it from the fevers known by the names of malignant, nervous, asthenic, putrid, and bilious—in fact, from the fever which we now know under the denomination of typhoid. He then describes the varieties of contagious typhus under the names of pestilential or oriental typhus (the plague), perhaps also occidental typhus (the yellow fever of America) and ordinary typhus. Of the latter he says that it is peculiar to Europe and we must include under it, *but only as so many varieties*, the typhus of hospitals and lazarettes, of prisons, of camps, of vessels, and of besieged cities, showing clearly that by it he means what we understand as typhus fever and that he was quite aware of the circumstances under which it flourishes. In Section VI. of his work he discusses the causes and modes of development of the disease. He says that it is always produced by contagion and that one attack of it almost always destroys for a certain time, but rarely for the whole of life, the susceptibility to the disease. He says that the contagion is spread by means of clothes, woollen stuffs, furs, linen, dirty bedclothes, and even by beds of straw or of hay on which typhus patients have lain. He disputes the view that the air of marshes has anything to do with the disease, pointing out that it produces fevers of the intermittent type. For him overcrowding is the cause of typhus fever, although he gives all credit to previous observers in the following sentence: "Army doctors by exact researches have been the first to show us under what circumstances and how the air can become the cause of typhus. R. Minderer, D. Monro, J. Pringle, and others have specially pointed out the dangers which air produces when it is overcharged with human exhalations. *There is in truth the source of the contagious matter and of the contagion of typhus.* It is equally recognised and too much confirmed by terrible examples that the exhalations of healthy men crowded and pressed together in too small a space have also the most harmful influence upon health. In prisons, houses of correction, small rooms of vessels, and in all the establishments where many men otherwise healthy live together in too great a number the air offers the same danger." He also insists that the disease may be avoided by preventing overcrowding: "As the atmosphere of hospitals, or of any other establishment, deteriorated and overcharged with exhalations, especially with exhalations of sick persons, is the only originating cause of typhus, and as the best method for preserving against this terrible disease consists solely in diverting these causes and in insuring a pure and respirable air, every authority, as soon as it is convinced of the importance and utility of this object, should take care to have recourse to measures which are the most salutary and the most suitable to attain this end. Such is certainly the duty of Governments: they watch over the sick with so much solicitude, they go to so much expense for food, medicines, and commodities of all kinds, and why should they neglect to pay attention to that which is the most necessary to the sick, to the purity of the air as the indispensable element of life, and of which the bad qualities are so often dangerous?" The next sentences are so remarkable and so much in advance of the time that I am sure I shall be pardoned for quoting them also: "What is there beneficial to suffering humanity when in a hospital and in a military lazarette a considerable number of sick persons are found crowded together and infected one after the other by the foul air? Would it not be more suitable to place these sick persons in barns or in attics in the open air than to crowd them in rooms? One would avoid in that way many dangers and misfortunes. One is even sometimes prodigal in providing warmth for sick persons. Why should one not be so in ensuring pure and sufficient air? Air is more useful than warmth. Want of warmth can sometimes be replaced by diet or medicines; want of air can never be replaced, either by the best diet or by the most expensive remedies. Civil and military authorities ought never to lose sight of this important truth. It is the duty of all those who are called upon to work for the good of humanity to have their minds imbued with this idea in order to attain the desired object." It is thus quite evident that this author in the early years of the nineteenth century had a perfectly clear idea of what typhus fever was, of its causes, and of the way to prevent it. He says in the most positive manner that it is a distinct disease from the other continued fevers which we now know as varieties of typhoid.

The most important early work on typhoid fever, however, is that of M. Louis, the first edition of which appeared in 1829 under the title of "Researches on the Diseases Known under the Names of Gastro-enteritis, Putrid, Adynamic, Ataxic, or Typhoid Fever," &c. It was dedicated to M. Chomel, Professor of Clinical Medicine at the Paris School. In this first edition M. Louis describes, with the hand of a master, typhoid fever in the minutest manner. He maintains that the ulceration of the Peyer's patches is its characteristic lesion and he says: "*Except the alteration of the elliptic patches* all the lesions of the mucous membrane of the smaller intestine observed in cases of the typhoid affection existed in persons who had succumbed to very different acute diseases." And again: "The elliptic patches of the small intestine having only shown alterations in the subjects dying from the disease which is the principal object of these researches, this alteration having been constant, ordinarily very severe, always developed according to the same law, whether death has arrived after eight days of the disease or after a much more considerable length of time; and in some cases, so to speak, the only lesion; it must not only be considered as special to typhoid affections, but as forming their anatomical character just as tubercles form that of phthisis, whatever has been the cause which has excited their development." He also, even in this first edition, describes the "*taches roses lenticulaires*" (N.B.—He calls them thus, by other writers they are generally known as "*taches rosées*"), their distribution and successive crops. With regard to the causes he says: "While the causes of enteritis are often evident, those of the typhoid affection are unknown." And again: "The most profound obscurity then reigns over the causes of the affection we are considering." The second edition of the work was published in 1841 and was also dedicated to M. Chomel.[1] In the preface to this edition he refers to the confusion which previously existed as to the continued fevers and says triumphantly: "Now that the confusion has ceased it is recognised that the fevers of Pinel, apart from the plague, only form one and the same disease, of which the anatomical character consists not in an inflammation of the stomach and intestine but in a profound and special lesion of the elliptic patches of the small intestine. Those who up to this time had defended with the greatest energy the doctrine of the fevers have abandoned their point of view and have recognised for the most part, as M. Chomel has done, the exactitude of the facts which I have observed and that of the conclusions which I have deduced from them.[2] This change of opinion has taken place not only in France but everywhere where observant medical men have followed the movements of science; and among foreigners the American medical men have been the first to recognise the correctness of my researches." He then quotes a number of American medical men "who, having studied for the most part the typhoid affection at Paris, have afterwards many times observed it in their own country with the symptoms and anatomical characters which I have described." In this second edition the chief additions that he makes are as follows. In the first edition he had stated that the "*taches roses*" were found in other diseases. In this one he says: "Since the publication of this work I have in vain searched for the spots in question on a number of patients attacked with other acute affections than typhoid fever; and I presume that being less familiarised with the typhoid spots 10 years ago than I am now I must have confused small papulæ with the eruption in question, which explains the apparent contradiction which I have just pointed out." This is the confession of a great and truthful observer. Further on he complains that "the state of the viscera of individuals who have perished from the different epidemics of typhus has often been neglected; and in this case the most certain and easy means of assuring oneself of the identity or difference between typhus and the typhoid affection escapes us." He then quotes M. Gaultier de Claubry and authors of other writings and says that "after a fashion these descriptions, although assuredly very incomplete, seem nevertheless to show, as far as they go, that the comparative study of the symptoms indicates the identity of typhus and the typhoid affection." It will be noticed how very guarded this sentence is, but M. Louis was not content with that very guarded statement, for he goes on instantly to make the following astute remark: "One cannot be too much astonished, however, in admitting this identity that a formidable accident, the perforation of the small intestine, has not fixed the attention of those who have described epidemics of typhus." And only three pages further on he says: "From the present time it must be acknowledged that every acute affection which is not accompanied in its course with the special alteration of Peyer's patches is not a typhoid affection, although one does not find in the autopsy the signs of any other affection, and thus the typhus fever of the English is necessarily a very different disease from that with which we are engaged." And then speaking of the observations of Dr. Shattuck of Boston he adds: "That which reasoning forces us to admit direct observation has proved, and we must recognise henceforth that there exist in England, and in London in particular, two febrile affections hitherto confounded together, but really very distinct, which only resemble one another in a general manner, of which one only attacks young persons, is accompanied ordinarily from the outset with local symptoms in the abdomen, afterwards with an eruption of *taches roses lenticulaires;* whilst the local symptoms, the diarrhœa, the meteorism, are more or less completely absent in the other which is accompanied by an eruption very different from the first and also much more abundant, and attacks persons of every age." He adds much to his chapter of causes and points out that in typhoid fever "passing the night in places situated low down and inhabited by too many persons cannot be one of the causes, as only the eighteenth part of the cases fulfil this condition." He actually gives one case, "Observation 54 bis," where the use of a putrid water in which a certain amount of chopped-up hay had been mixed was followed by a well-developed and fatal case of typhoid fever in which the ulcerations of the Peyer's patches were found after death. With regard to the question of contagion, which he did not touch in the first edition of his work, he comes positively to the conclusion that it is a contagious disease, and that the Paris physicians had denied this because in a great city it is difficult to trace the course of contagion. He quotes largely from the work of M. Gendron of Château-du-Loir on epidemics of small places to prove that the disease is transmitted directly and indirectly from person to person. He also quotes from the same author some remarkable instances proving the immunity conferred by an attack of the disease, and at the same time proving its contagious character. These are so interesting that I think them worth quoting, as follows:—

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[1] In this edition the title was somewhat altered, the name *typhoid* fever being given a prominent position before the other names of the disease.

[2] In a footnote he here acknowledges the recognition given him by Professor Forget in his treatise on Follicular Enteritis, which had just been published.

1. Three journalists contracted the disease at a certain house; two communicated it to their families; the third did not do so, he was looked after by his wife who had had the disease several years before.

2. A domestic servant of Contereau transmitted typhoid fever to his sister, the niece of his master and mistress, and these visited her without danger. They had had the typhoid affection four years before.

3. At Petit-Gênes a young man infected all who looked after him except his father and mother; these had both previously had dothinentérie; the husband 20 years and the wife two years before the epidemic which this very son started.

4. In 1829 the same disease was imported into a fresh family at Petit-Gênes and did not go beyond it, in spite of the visits of the inhabitants of the hamlet, which had already been once attacked.

5. At eight years apart two epidemics attacked Coëmont and the second spared all those whom the first had not spared.

He concludes, then, first that the disease observed in these country places by MM. Bretonneau, Leuret, and Gendron whether in the sporadic or epidemic state was unquestionably typhoid fever, because the characteristic anatomical lesion was commonly found among those who died from it and "it must be recognised therefore that the typhoid affection is contagious, at any rate in the departments." But he adds that others have since made similar observations in Paris. Thus, M. Putegnat "has reported that after a visit made to a person who returned from a village where typhoid fever prevailed a woman was attacked by this disease and a few days afterwards her husband and their six children were also attacked. A single person escaped—she was 82 years of age. M. Putegnat also reports other similar facts which leave no doubt as to the contagious character of the disease." And he finally concludes: "It seems to me henceforth impossible, after all that goes before, to deny the contagious character of the typhoid affection, even in Paris."

I will next draw your attention to the work of Professor A. E. Chomel entitled "Leçons de Clinique Médicale (Tome I., Fièvre Typhoïde)," published in 1834, but delivered before then. Dr. Chomel considered typhoid fever a separate and distinct disease from typhus fever and gave it the name of typhoid fever. In his introductory remarks he says that the fevers described by different authors, including himself, "under the name of grave continued fevers, under whatever form they show themselves, whether inflammatory, bilious, mucous, adynamic, ataxic, nervous, are only varieties of one of the same affection which has received different names (entero-mesenteric fever of MM. Petit and Serres, intestinal exanthema of M. Andral, *dothinentérie* or *dothinentérite* of M. Bretonneau, *iléo-diclidite* of M. Bally, follicular enteritis of many pathologists). We shall preferably call it by the name of *typhoid fever* or *disease*, because of the analogy which it offers in its symptoms with the typhus of camps." He goes on to add that the various fevers mentioned above have common characters which forbid them being considered as separate diseases "*and are especially bound together by a series of anatomical lesions which one does not meet with in any other disease.* The typhoid affection will therefore occupy in nosology a position of great importance because it almost takes the place by itself of a whole class of diseases." He then describes most minutely the symptoms and course of the disease, describing, among other things, the special eruption in the following words: "One sees appear ordinarily from the seventh to the ninth day that altogether peculiar eruption which is special to typhoid fever and consists in small *taches rosées*, disappearing by pressure, of from half a line to two lines in diameter, round in shape, without elevation or scarcely elevated above the skin, scattered over the abdomen, sometimes over the chest, more rarely over the thighs, the arms, and the forearms." Further on he points out that "the *taches rosées lentiaulaires* are easily distinguished from the petechiæ and from the bites of fleas, because in these latter there is extravasation of blood at the surface of the dermis, and that their colour, instead of lessening under the influence of pressure, becomes more pronounced by the discolouration of the skin which surrounds them. In the typhoid spots, on the contrary, the redness disappears altogether, as in erysipelas, where there is evidently congestion, and where, when the pressure ceases, one sees the redness reappear immediately." Further on, again, he points out that in a certain number of cases there is intestinal hæmorrhage and sometimes perforation, of which he says: "Perforation of the intestinal walls is the most grave of the accidents which can happen in the course of the typhoid affection, for it almost inevitably results in the death of the patient." He mentions that M. Louis reported that he had observed intestinal perforation eight times in 55 persons who had died from typhoid fever, a proportion of one in seven. In discussing the lesions produced during the course of the disease he says: "The anatomical lesions which constantly or almost constantly accompany the typhoid affection are situated in the follicles of the intestines and the mesenteric glands. These are the only lesions which one meets with in almost every case." He includes in the follicles of the intestines the isolated ones (Brunner's glands) and the agglomerated ones (Peyer's patches) and further on he describes minutely the ulceration of the follicles. Like all the other authors of the time he finds that "the causes of typhoid fever are involved in the greatest obscurity." With regard to the question of contagion he points out that "there is a great difference of opinion among medical men—the majority in France deny every kind of contagion in this disease. A few, however—perhaps 1 per cent.—think that typhoid fever ought to be classed among the contagious diseases." He then states the arguments of the non-contagionists, which he says were generally received and admitted without opposition until the time when M. Bretonneau in 1829 adopted the opposite opinion. He points out that the first reason why contagion has been denied to this malady "is that of all the persons who can surround a patient attacked with typhoid fever there are few who are susceptible of contracting the disease. One understands in effect that the father, the mother, the doctor, the nurses, many of the sick in hospitals, are immune to the contagion either because most of them have already passed the age at which the typhoid disease is most commonly developed, or because they have already been attacked by it, or, lastly, because they are among the number of those who are immune by constitution. Another reason is that in hospitals on account of the good ventilation such diseases even as small-pox are not readily transmitted from one patient to another." He also points out that the negative proofs on which the anti-contagionists rely are entirely from observations made in Paris. "But it is not in cities as large as Paris that one can study contagious diseases from the point of view of their transmissibility, because of the difficulty, or even of the impossibility, in most of the cases to trace there the course of the contagion. ...... It is not, therefore, by negative proofs collected in a city like Paris that one can support an opinion unfavourable to contagion." Typhoid fever, according to him, only affects the same person once. "This circumstance is an important fact, for there are only a few diseases which attack but once the same person, and among these diseases there is not one which is not obviously contagious; typhoid fever would then be the only exception to this law if it were not contagious like the other diseases with which it shares this important character. Lastly, another point which is in favour of contagion is the analogy which exists between the typhoid affection and the typhus of camps, of which no one disputes the contagious character." He then discusses the resemblances and differences between these two diseases and formulates his conclusions as follows: "1. The opinion adopted by most French medical men that the typhoid affection is not contagious cannot be admitted as demonstrated. 2. If this disease is contagious it is only so to a feeble degree and with the concurrence of circumstances as yet ill-defined. 3. If further observations show in typhus fever anatomical lesions resembling those which one meets with in the typhoid disease the identity of the two affections would be placed beyond doubt and the question of contagion would be solved." Thus, after his minute and accurate account of typhoid fever and his evident conviction that it is a separate disease, he is obliged from his ignorance of typhus to suggest that it may be possible that after all they may be the same disease.

I am relieved from the necessity of describing the works of various other authors before 1835, as in that year two most important memoirs were awarded prizes by the Royal Academy of Medicine of Paris and were published in the memoirs of that academy. These memoirs were answers to the question, "faire connaitre les analogies et les différences qui existent entre le typhus et la fièvre typhoide dans l'état actuel de la science." The first was by M. Gaultier de Claubry. In this paper he, like everyone else up to that time, considers the oriental plague to be a variety of typhus fever. He states that MM. Petit and Serres gave to a typhoid outbreak at the Hôtel Dieu in 1812 the name of "fièvre entéro-mésentérique" and that they, like MM. Louis and Chomel, consider it a separate disease. Even in the page of introduction to his memoir M. Gaultier de Claubry shows the bent of his mind, for, after describing typhoid fever as "that grave continued fever, so-called by MM. Louis, Chomel, Bouillaud, &c., which has as constant anatomical characters the alteration of the elliptical patches and scattered follicles of the small intestine and that of the lymphatic ganglia of the mesentery," he goes on to say: "We are about to set forth a complete parallel between the two affections (typhus and typhoid fevers) in order to bring out the analogies and the differences, *if there are any*." And so we find that quite early in his memoir at the end of the second chapter he actually concludes with (under the head of "Symptomatology") "*Typhoid and typhus fever present not only analogy but the most perfect resemblance*," and this apparently merely because they both present different forms with different degrees of intensity. Later he tells us that in the two fevers the lenticular eruption is the same but that in typhus it is more abundant and petechial, but that sometimes it is the same in typhoid, and in this latter statement he is quite correct, as the eruption in typhoid may occasionally simulate that of typhus fever so completely as to be indistinguishable from it. I remember well an instance in University College Hospital of a young woman, a patient in one of Sir William Jenner's wards, who contracted *typhoid* fever while in the hospital, and developed the *typhus* rash so completely that one of the best clinical physicians of the time brought his class to see what the typhus eruption was like. The girl was sent to the London Fever Hospital as a case of typhus fever and she died there with ulceration of the Peyer's patches. There was no doubt, therefore, that the girl had typhoid fever. It was known from whom she contracted it and it was quite certain that she could not have contracted typhus fever while in the hospital.

Of the intestinal lesions, as of the symptoms, M. Gaultier de Claubry concludes that because in typhus fever alterations have sometimes been found in the mucous membrane of the intestines "there is not only a greater or lesser analogy but an *incontestable identity* of organic changes in the two fevers," and he makes this statement in spite of the fact that a little further on he praises the work of M. Lombard of Geneva who says that throughout the six years during which he has studied the subject with the greatest attention he has never seen a single case of typhoid fever in which the intestinal canal did not present after death the lesion of the elliptical patches of the smaller intestine, but that he saw with the greatest surprise that the cases (of typhus fever) at Glasgow and Dublin had no such lesion or affection of the mesenteric glands, and that this was the general experience of the medical men there. As to causes, M. Gaultier de Claubry shows that all authors agree that overcrowding is the cause of typhus fever, but he points out that Louis showed that this could not be the cause of typhoid fever, as only one-eighteenth part of the subjects of it were found to be under that condition, and that most of the cases were among the newcomers to Paris. It is a pity that M. Gaultier de Claubry did not pay more attention to this point. If he had he would hardly have concluded his memoir with the sentence: "Typhus fever and typhoid fever are one and the same disease to which it would be convenient to give the name of typhode fever in order to avoid the expression typhoid, which only indicates an analogy of form, and the word typhus which frightens people."

The other memoir was by M. Montault. It, like the former one, is a very exhaustive memoir, but, unlike it, commences without any *parti-pris*, as he gives no hint of any preconceived notions; indeed, he says in his introduction that he has "specially shown himself jealous of giving proof of a mind free from preconceived ideas and occupied by an ardent love of truth and guided by observation and reasoning after the well-known precepts of Hippocrates, Baglivi, and Bacon." In the first two parts of his memoir he gives what he calls the history of the two diseases, under which he includes causes, symptoms, lesions, and treatment. In the third part he discusses the analogies and differences between them. Persons of all ages are exposed to attacks of typhus, while it is certainly not so for the typhoid fevers (he always speaks of typhoid fevers, not "fever"). Typhoid fever often occurs without overcrowding. Contagion, generally admitted for typhus, is not proved for typhoid fever, which is also more often sporadic than epidemic. He here quotes Hildenbrand as distinguishing completely typhus from the typhoid fevers, because of contagion which is peculiar to typhus. He then points out the differences of the symptoms of the two diseases and says that it is only in typhoid fever that death is sometimes caused by peritonitis following perforation of the intestines, and with regard to the ulceration in the intestines he says that one cannot in typhus fever assign different degrees or various forms to the lesion of Peyer's patches "because it is now probable that this lesion is absent in typhus fever." He also notices the differences in the times of the eruptions: "In the typhoid fevers the special eruption appears from the eighth to the twelfth day; in typhus from the fourth to the seventh day. This eruption which is constant in typhus does not constantly exist in the typhoid fevers. It is more general and more abundant (that is, the spots are more numerous) in typhus. It appears in the nervous period in the typhoid fevers; it disappears on the contrary in the nervous period of typhus. According to M. Rochoux it forms a morbilliform eruption in typhus and consists of slight elevations in typhoid fever; according to M. Chomel this eruption takes place on the abdomen and chest in the latter disease, whilst in typhus the face and the limbs are especially affected by it; lastly, petechiæ are rare in typhoid fever but very common in typhus." At the end of his memoir he gives a summary of the analogies of the diseases in the form of a table, but although he thus clearly points out the differences between these diseases he does not commit himself to the statement that they are two different diseases. He contents himself by stating that Hildenbrand, F. de Sauvages, and P. Frank regarded them as different diseases; that M. Bouillaud recognised a "want of identity" at a certain period of the diseases; and that M. Brettoneau had expressed no definite opinion on the matter. It is a great pity that the modesty of M. Montault was so great as to prevent his stating definitely the opinion to which his admirable researches undoubtedly led him. Had he done so it would, perhaps, have prevented the erroneous views of M. Gaultier de Claubry from taking possession of the medical profession in France.

A report by MM. Louis, Bricheteau, Bouillaud, Double, Bally, and Andral, on a paper by M. de Larroque on "The Treatment of Typhoid Fever by Purgatives," published in the *Bulletin de l'Académie de Médecine* for 1836, shows how vague was then the knowledge of typhoid fever even among those who knew it best, for they suggest that "the pyrexia, called in France 'typhoid fever,' *may be* nothing else than a gastro-intestinal inflammation," and M. Bouillaud defines it as follows: "Typhoid fever, or adynamic fever, or entero-mesenteric fever, or dothinentérite, or iléo-diclidite, &c., consists in the inflammation of the small intestine and its follicles plus a *typhoid element*, the nature of which is not agreed on." On the other hand, during the discussion M. Rochoux says positively, "Typhus and typhoid fever are two essentially distinct diseases, as M. Petit has proved, and as I have stated in a treatise myself."

At about the same time that Dr. Lombard of Geneva was making his observations which led him to the conclusion that there were "two distinct and separate fevers in Great Britain, one of them identical with contagious typhus, the other a sporadic disease identical with the typhoid fever or *dothienenteritis* of the French,* Gerhard and Pennock of Philadelphia were arriving at the same conclusion from observations of an epidemic of typhus which prevailed in that city in the spring and summer of 1836. Both had previously studied the enteric fever in Paris and were familiar with it in their own country. They at once recognised the difference of the new disease, and after a time they were never deceived in their diagnosis." Their observations were published by Gerhard in February and August, 1837. Gerhard maintained that the typhus of Philadelphia was identical with British typhus, and with the gaol, camp, ship, petechial, or spotted fever, and that it was eminently contagious, while, on the other hand, typhoid fever was rarely communicated. He showed that the lesions of Peyer's patches and of the mesenteric glands, invariably present in the latter, were never found in the former, and remarked that English observers erred in regarding the intestinal disease as a mere complication of typhus. He insisted on the marked difference between the petechial eruption of typhus and the rose-coloured spots of typhoid fever, and he showed that a peculiar train of symptoms very different from those of typhus was associated with the intestinal affection. M. Valleix of Paris, in a review published in January and February, 1839, thus alluded to Gerhard's observations: "M. Gerhard établit d'abord un fait bien important, c'est qu'il peut exister, et qu'il existe en effet, concurremment dans le même pays, deux maladies, qu'on peut parfaitement diagnostiquer, et dans lesquelles on peut prédire pendant la vie du malade, les lésions qui seront trouvées après la mort; ce sont la fièvre typhoïde et le typhus proprement dit."

After this several authorities, especially Dr. Staboroh, Dr. Shuttuck of Boston, M. Valleix, and M. Rochoux, published memoirs pointing out the differences between the two fevers. Of the last mentioned Dr. Murchison says: "He insisted that nothing could be more unlike than the eruptions of the two fevers and that while typhus was highly contagious and generally believed to result from overcrowding the contagious character of dothienenteritis was doubtful and it was independent of overcrowding" (Rochoux, 1840).

I may here insert the opinion of the great French clinician, Trousseau, who says: "Dothienentérie is a general disease, acute, febrile, very akin to the eruptive fevers of which we have spoken and with which it offers more than one striking analogy." He also says: "La contagion de la dothienentérie est incontestable."

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* See two letters by Dr H. C. Lombard in the *Dublin Journal of Medical Science*, Vol. 10, 1836, and a paper by the same author in the *Gazette Médicale de Paris*, March 2nd, 1839.

On Feb. 6th, 1840, Dr. H. C. Barlow read a very important paper on "The Distinction between Typhus Fever and Dothienentérie" before the Parisian Medical Society, an abstract of which will be found in THE LANCET of Feb. 29th of that year. He insisted that these two fevers were not only different in their lesions but also that "the *fièvre typhoïde* of France is an endemic disease; it is endemic in those localities, as in Paris, where it principally prevails and where the influence of contagion is extremely doubtful and is by many positively denied. The typhus fever of Great Britain and Ireland on the contrary is a highly contagious disease." Further on he says: "I would suggest that two diseases so different in their modes of origin, however nearly in the course of their symptoms they may come to resemble each other cannot be essentially identical. Dothienentérie chiefly attacks those who have only been a short time resident in Paris or in a large city; typhus fever observes no such distinction of persons; the former rarely occurs above the age of 40 years or below that of 10, the latter on the contrary very frequently does. Dothienentérie is at its maximum in autumn and at its minimum in winter. ...... In typhus no such connexion is observed to exist and that disease is often at its greatest height in winter when the former is comparatively rare." He also points out that in typhoid fever "diarrhœa is one of the earliest and most constant symptoms. It usually sets in at the beginning of the disease and continues to its close. It does not appear to be essential, as three fatal cases are mentioned by M. Louis in which it did not occur, neither is there any obvious relation between its amount and the degree of organic lesion which exists, yet its occurrence is almost invariable. In typhus an opposite state prevails and diarrhœa is comparatively rare." After mentioning other differences he describes the eruptions of the two diseases with the greatest minuteness and accuracy. "At about the eighth or ninth day the typhoid eruption, consisting of lenticular rose-coloured spots, *taches rosées*, appears on the abdomen, back, and chest; it is not an abundant eruption and not always present. The spots are about a line in diameter, regular in form, slightly elevated, and disappear on pressure, but return again. They come out in succession, four days being the average duration of each." After describing the sudamina he adds, "Petechiæ have been chiefly noticed in particular epidemics. They vary in diameter from one to several lines and neither project nor disappear on pressure. Vibices occasionally occur." On the other hand, "in the typhus fever of Great Britain and Ireland the eruption is chiefly petechial, often mixed with vibices, appears earlier, on the fourth or fifth day, sometimes before, and is commonly profuse, the amount of eruption bearing a certain ratio to the intensity and duration of the disease. The duration of dothienentérie may be stated on an average of from 20 to 30 days. ...... The average duration of typhus in 43 fatal cases mentioned by Dr. Reid was 12½ days ...... so that typhus appears to run its course much more rapidly than dothienentérie." He sums up the differences between the two fevers as follows: "A difference in the manner of origin, a difference in the seasons of occurrence, and a difference in the modes of attack; a difference in the series of symptoms, a difference in the external appearance, and a difference in the duration of the diseases; a difference in the ages at which they occur, a difference in the sexes in which they principally prevail, and a difference in the mortality which they respectively occasion. While the great and crowning difference of all is the existence of a particular anatomical lesion in one, and the absence of any obvious anatomical lesion in the other. Surely two diseases which differ in all these particulars cannot be identical." No wonder that Dr. Murchison says: "This paper has received less attention from subsequent writers than it deserves." I will go farther than that and will say that although previous writers had foreshadowed the differences between the two diseases, and although some of those writers whom I have mentioned had gone so far as to declare that the two diseases were different from one another, Dr. Barlow was the first man to give a detailed and complete account of the differences between the two diseases and to establish once and for ever that they are entirely distinct from one another. The only important fact in connexion with the two diseases that he does not point out is the difference in their *causes*.

In the same year—viz., on April 16th and 23rd, 1840—Dr. A. P. Stewart read a paper, also before the Parisian Medical Society, entitled, "Some Considerations on the Nature and Pathology of Typhus and Typhoid Fever applied to the Solution of the Question of Identity or Non-identity of the Two Diseases." This paper is an admirable summary of the state of knowledge on the subject at the time and contains an excellent description of the two diseases and their differences. He alludes to the cause of typhoid fever, of which he says: "With regard to the producing cause of typhoid fever all is vague and uncertain, ... but what chiefly concerns us to know is whether the conditions we have seen to be so powerful in the production of typhus are the same, or anything like the same, in regard to typhoid fever. Exactly on this point Louis remarks: 'No more can the dwelling in places, low and inhabited during night by too great a number of individuals, figure among the causes in question, one-eighteenth only of the patients being in that condition,' and he concludes from a comparison of all the assigned causes with the facts ascertained by himself in these remarkable words: 'The deepest darkness, then, prevails regarding the causes of the affection under consideration. Chomel likewise uses the same words in beginning his third article: 'The causes of typhoid fever are wrapped in the greatest obscurity.'" As to Dr. Stewart himself he merely says without hazarding any decided conclusion on a point so keenly debated: "I would simply direct attention to the differences as regards the probable origin and propagation of the two diseases which the foregoing facts appear to establish and also to the interesting question whether, if typhoid fever really depends on and is propagated by a specific poison, that poison is or is not generated under the same circumstances as the infection of typhus." So that as far as the cause is concerned Dr. Stewart does not advance us at all, neither does he venture to say that typhoid and typhus fevers are distinct diseases, for he sums up the matter as follows: "On a review, then, of all that has been advanced, it would appear that typhus and typhoid fever present important differences, as regards their probable origin, their approximate causes, their course, many of their symptoms, their diseased appearances, and the treatment applied to each. Are they, then, identical, or are they not? I feel that it would be presumptuous in me to hazard a direct reply; nor do I demand an answer in the affirmative merely on the faith of what I have stated. All I can ask or wish for is careful, extensive, and minute inquiry without prepossession or love of system, and a satisfactory solution must soon be arrived at." So that he does not really lead us as far as Dr. Barlow had already done.

In the year 1841 a work entitled "Traité de l'Entérite Folliculeuse (Fièvre Typhoide)," by C. P. Forget, Professor of Clinical Medicine at the University of Strasburg, was published in Paris, consisting, in fact, of lectures previously given by that physician to his students, to whom it is dedicated. (The preface is dated November, 1840.) In these lectures he speaks of the *essential distinctions* between typhus and typhoid fevers, saying that they have only been determined within recent times. He gives Hildenbrand the credit of being the author who had done more than any other to point out the specific nature of typhus fever, but he does not agree that the other fevers from which Hildenbrand distinguishes it are necessarily non-contagious. He then discusses the views of M. Gaultier de Claubry and other authors who maintain that typhus and typhoid fevers were the same diseases. M. Forget excuses himself for quoting so many authorities by saying that he has not had the sad privilege of observing epidemic typhus. He is evidently much impressed with the views of M. Gaultier de Claubry and admits that it is possible that many of the grave febrile affections referred to may be identical, but he defines his own object as follows: "That which I profess to show is that our *sporadic* typhus *nostras, typhoid fever*—in a word, the grave continued fevers of our country—are, and certainly always have been, associated with follicular enteritis. *Let this be well understood. We do not profess to talk of that which we have not seen* (i.e., of typhus fever); it is follicular enteritis, commonly called typhoid fever, which is going to occupy us exclusively." He is perfectly clear about the fact that the disease has this special lesion and he gives the following definition: "Follicular enteritis is defined by itself—that is to say, that the lesion which names it is its fundamental character. Follicular enteritis is the inflammation of the intestinal follicles, as pneumonia is the inflammation of the lung." And again: "Follicular enteritis is a material fact, as pneumonia, hepiditis, cancer, variola, &c. Why, then, should we refuse to make a disease of it? ...... What we have to do here is to establish the reality of follicular enteritis as an evident morbid fact; it is to recognise its right to a place in the catalogue of diseases.[3] For him, among several alterations in the intestinal canal those of Peyer's patches are the most characteristic, and he describes them in great detail, referring to the observations of Bretonneau, Louis, Chomel, and Montault on perforation of the intestine in this disease. Although he mentions the *taches rosées* he evidently does not consider them as especially characteristic of the disease any more than the sudamina or the petechiæ which he also mentions. As to the cause of the disease, while he considers that it may be produced by foul air and decomposing foods, he says that the causes "sont très variables et n'offrent rien de spécifique." It is evident, however, that he attached some importance to foods as a possible means of conveying the disease, for he says: "Is it not, indeed, singular that some would deny that food, for instance, has the power of directly producing follicular enteritis, when they attribute to it without difficulty gastritis, colitis, and villous enteritis itself?" After quoting a number of other authors, some of whom maintain that the disease is contagious and others that it is not, he gives his own opinion as follows: "As for me, a pupil of the Paris School, I have denied the contagion until after my removal to the country, as indisputable facts showed me that typhoid fever can affect persons who stay near sick persons. Whether it is by the inoculation of a specific virus (contagion) or by inspiration of air vitiated in any other manner (infection) I do not know; but this is positive, that the disease *is communicated* in certain circumstances somewhat rare and still undetermined." This sentence, I think, expresses the view that is held most generally now. However, he in fine concludes "that there is nothing invariable and essential in the causes of follicular enteritis; nothing essential and invariable except follicular enteritis itself."

Such was the position when Dr. William Jenner (afterwards Sir William Jenner, Bart., G.C.B., one of the ablest Presidents the College ever had) undertook the investigation of the question. Having been resident medical officer of the London Fever Hospital he had had an excellent opportunity, of which he made the best use, of making observations on cases of both typhus and typhoid fevers, and in 1849 his paper "On the Identity or Non-identity of Typhoid and Typhus Fevers" appeared in the *Monthly Journal* and was published in a separate form by John Churchill in 1850. In the introduction to this paper he points out "that with few exceptions British physicians have laboured to prove that typhoid and typhus fevers are identical. The results obtained by this analysis justify the assertion that they are essentially distinct diseases." He commences by stating the differences between scarlet fever and small-pox and in a masterly manner proceeds in his paper to show that similar differences are observed between typhoid fever and typhus fever. "We assert that small-pox and scarlet fever are different diseases for the five following reasons: 1st. In the vast majority of cases the general symptoms differ. 2nd. The eruptions, the diagnostic characters if present, are never identical. 3rd. The anatomical character of the one is never seen in the other. 4th. Both being contagious diseases, the one, by no combination of the individual peculiarities, atmospheric variations, epidemic constitutions, or hygienic conditions, can give rise to the other. 5th. The epidemic constitution favourable to the origin, spread, or peculiarity in form or severity of either has no influence over the other excepting that which it exercises over disease in general." With regard to the third of these he explains as follows: "By the anatomical character of a disease I intend to signify that lesion or those lesions of structure which are the invariable concomitants of a disease if it has continued for a given time, which time must be determined by a separate series of observations for every distinct affection. The anatomical character is not, be it remarked—and this is of immense importance—necessarily the cause of the disease, for it may be merely a symptom; but then, if the disease be not cut short by death it is an invariable symptom." Jenner saw that the crucial question was the determination of the facts with regard to the intestinal lesions. He remarks: "London alone of all the cities of Europe, from the fact of fever, with and without intestinal disease, being almost constantly present within its bounds, afforded a field for observation capable of setting the vexed question at rest. In Edinburgh, writes Dr. Christison, the intestinal lesion is seen often enough only to prevent physicians being ignorant of its characters. In Dublin it appears to be equally unfrequent, while on the continent fever without lesion of the agminated glands is so rare that many eminent practitioners have doubted the existence of such an affection. The London Fever Hospital, by collecting within its walls cases of continued fever from all parts of the great metropolis, offered peculiar facilities for its study." During two years he made notes of nearly 1000 cases of acute disease, of which 66 were fatal cases of continued fever which were examined by him after death. This was necessary, as it was essential that the presence or absence of the intestinal lesion should be demonstrated. Of the 66 cases he found that in 23 the disease of Peyer's patches existed. These were cases of typhoid fever. In the remaining 43 the agminated glands, so far as the unassisted eye could determine, were in a healthy condition and these were cases of typhus fever. He then describes with the greatest minuteness the difference in the symptoms of the two diseases and concludes by combating two assertions that had been put forward "to account for the differences in symptoms which existed in continued fever with and without entero-mesenteric disease." 1. That typhoid fever is merely typhus fever complicated with lesions of a particular organ and it is therefore to be expected that certain symptoms referable to, and dependent on, that lesion will be present and so far modify the symptoms of the disease. He maintains, on the contrary, that the general symptoms of the two diseases in the cases he examined differed widely, "such differences having no apparent connexion with the local affection but being probably, like it, dependent on some common cause acting on the whole system simultaneously. Thus the remarkable differences in the kind—no small amount—of the rash of the two diseases, and the tendency to local inflammations, to erysipelas, and to ulceration, observed in the cases of typhoid fever here analysed, cannot with any show of reason be considered to have been dependent on the disease of Peyer's patches—i.e., in the same way as the abdominal signs undoubtedly were. The fact also that the duration of typhoid fever, and even of fatal cases of it, is considerably greater than is that of typhus fever also struck me very forcibly. The short comparative duration of the cases of typhus fever here considered is another remarkable point of difference, totally inexplicable by the hypothesis that typhoid fever is typhus fever with intestinal ulceration. Had the cases eventually recovered it might have been said that the intestinal lesion prolonged the disease in the cases of typhoid fever, but that all the fatal cases of fever, with a local lesion of so severe a nature as that recorded to have been present in the cases of typhoid fever, should have had a much longer course than all those other fatal cases of fever in which no organic change of structure could be detected after death appears to me inexplicable on the supposition that the former is simply the latter disease, with this serious lesion superadded. Let me repeat, by this hypothesis, we are asked to imagine that death is retarded in fever by extensive ulceration of the small intestines and enlargement, softening, and even suppuration of the mesenteric glands. Surely it behoves the supporters of such a statement to bring forward cogent proofs of the identity of the specific cause of the two affections ere they ask us to admit its truth."

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[3] He thus gives the disease the name of what he regards as its important and characteristic lesion, calling it "follicular enteritis"—even a worse name for it than "enteric fever."

After pointing out other important differences he adds: "Thus tried by facts—i.e., by recorded symptoms and lesions—the assertion that typhoid fever is merely typhus fever with abdominal complication is completely refuted." 2. But another mode of explaining the differences which exist between the two diseases has been given—i.e., that the differences observed depend on variations in the epidemic constitution. These cases afford a complete answer to this assertion, for a majority of the cases here analysed of both diseases were observed during the same epidemic. "The cases of typhoid fever—which disease is rarely absent for a fortnight from the wards of the hospital—preserved their symptoms unchanged and presented the same lesions whatever the epidemic constitution that prevailed; the same is true of typhus fever. Cases of the latter disease are also rarely absent from the wards of the same institution. It is there common to see the patients occupying beds side by side and presenting respectively the well-marked characters of either disease. If, I repeat, the two affections were really the same disease, then the same epidemic constitution ought to have impressed on both the same general features, implanted in both the same local lesions, and given to both the same tendency to cadaveric change, and this allowing for all the modifying influence which the accidental presence of the abdominal lesions in the one and the absence from the other group might have occasioned. The analysis of every symptom and every lesion shows that the two affections were not thus assimilated by the prevalence of any particular epidemic constitution. But if this epidemic constitution, by any stretch of the imagination, could be supposed to change from week to week, to cause the case attacked to-day to have typhus fever, the individual who takes the disease to-morrow to have typhoid fever, still it could not account for the fact, as well established as any fact in medicine, that typhoid fever rarely, if ever, affects persons more than 50 years of age, while age exerts little influence in determining the occurrence of typhus fever. Thus, then, the assertion that typhoid fever is merely typhus fever modified by the prevailing epidemic constitution is as irreconcilable with facts as that the former disease is simply the latter with abdominal complication." He then repeats the distinctions between small-pox and scarlet fever and concludes: "If, then, the above are the grounds—and after mature deliberation I am able to assign no others—for the separation of small-pox from scarlet fever, I think it is indisputably proved that typhoid fever and typhus fever are equally distinct diseases—not mere varieties of each other, but specially distinct—specific distinction being shown in typhoid and typhus fevers, as in small-pox and scarlet fever, by the difference of their symptoms, course, duration, lesions, and *cause*."

Thus Jenner, as all who knew him knew, always had the courage of his opinions. He was not afraid, as some others before him had been, to state definitely, succinctly, and without circumlocution, the conclusions to which his investigations had led him, even though those conclusions were at variance, as he himself says, with the great majority of medical opinion at the time both in this country and on the continent. But this was not all. On Dec. 11th, 1849, Dr. William Jenner read a paper before the Royal Medical and Chirurgical Society entitled "On the Identity or Non-Identity of the Specific Cause of Typhoid, Typhus, and Relapsing Fever." For this purpose he analysed the cases admitted into the London Fever Hospital during the years 1847, 1848, and 1849, and the summary of his results is as follows: "In 1848 one-fourth of the cases admitted into the hospital had typhoid fever; while from 34 foci of typhus fever, yielding 101 cases, there was brought to the hospital once only a case of typhus fever and a case of typhoid fever from the same house; and during the same time among five localities affording nine cases of typhoid fever, one locality only ...... yielding a case of typhoid and one of typhus fever. That in 1849, although 18 foci of typhus fever yielded 51 cases and four foci of typhoid fever afforded 10 cases, not a single example of the two diseases being received into the hospital from one house occurred." And he concludes: "The facts contained in this paper appear to me to prove incontestably, so far as induction can prove the point, that the specific causes of typhus and typhoid fevers are absolutely different from each other. ...... I have throughout this paper expressed myself as if the specific cause respectively of typhoid fever, typhus fever, and relapsing fever was an influence emanating from the bodies of those affected with either disease. With respect to the contagious nature of typhus fever, I know no one who entertains a doubt. If typhoid fever be contagious it is infinitely less so than typhus fever. My experience leads me to regard it as contagious. Those who believe typhoid fever to be non-contagious while they admit the contagious nature of typhus fever cannot for a moment doubt the difference in the specific causes of the diseases. It would not, it ought to be observed, have weakened the force of the facts adduced if I had regarded these diseases as non-contagious, because the question here considered is not how the individuals respectively got the disease, but if the same cause, whether contagion or any other, can produce typhoid fever, typhus fever, and relapsing fever."[4]

Thus Dr. Jenner carries us, at any rate, one step farther. He not only asserts, as Dr. Barlow and others had done, that the two are distinct diseases, and proves it up to the hilt, but he also proves that they must have essentially different causes.

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[4] Transactions of the Royal Medical and Chirurgical Society, vol. xxxiii., 1850.

Dr. Murchison read a paper before the Royal Medical and Chirurgical Society on April 27th, 1858, entitled, "Contributions to the Etiology of Continued Fever, or an Investigation of Various Causes which Influence the Prevalence and Mortality of its Different Forms." In this admirable paper, describing the results of his observations at the London Fever Hospital, he establishes the following important points (besides many others) which I will give in his own words:—

1. Typhus and relapsing fever are quite independent of the season of the year, whereas typhoid fever is almost invariably most prevalent during autumn at the time that diarrhœa is most common, and it has been observed to be specially prevalent in seasons remarkable for their high temperature.

2. Sex has no influence over the prevalence of continued fever nor over that of any of its forms.

3. Typhoid fever is pre-eminently a disease of childhood and adolescence, at which periods of life we know that there is a marked proneness to enteric affections. Less than one-seventh of the cases of typhoid are above 30 years of age. Typhus and relapsing fever exhibit no predilection for youth—of typhus one-half, and of relapsing fever one-third, of the cases are above 30.

4. Typhus and relapsing fever appertain exclusively to poverty and destitution, and seldom or never occur among the wealthy except from direct contagion. Typhoid fever attacks both poor and rich without distinction.

5. In large cities typhus and relapsing fever are for the most part limited to those localities remarkable for the overcrowding of their inhabitants; and in country districts they are seldom or never met with except as the result of direct importation. Typhoid, on the other hand, occurs alike in the centre and suburbs of cities; in the crowded houses of the poor and in the spacious mansions of the great; and also in isolated houses and hamlets in the country, without any traceable sources of contagion.

6. When fever breaks out in a house or locality it seldom or never happens that some of the cases are typhus and others typhoid, but typhus and relapsing fever occur not unfrequently together.

7. Overcrowding with deficient ventilation and destitution appear to be the essential causes of typhus and relapsing fever and to be capable of generating them *de novo*, [?][5] while there is no evidence that they have any such influence over the production of typhoid fever.

8. There are many circumstances which tend to the belief that the emanations of decaying organic matter or organic impurities in drinking water, or both of these causes combined, are capable of generating [?] typhoid fever, but there is no authenticated evidence whatever to prove that such causes can give rise to typhus or relapsing fever.

9. Typhus is eminently contagious. Typhoid fever is also contagious, but in a more limited degree and possibly through a different medium. Again, typhus has in no instance been proved to communicate typhoid, nor typhoid to communicate typhus. An attack of either confers an immunity from a future attack of itself, but not of the other.

10. In all of the fevers there is not much difference in the mortality of the two sexes.

11. The mortality from typhus is greater among the very poor than among those in better circumstances. Typhoid fever appears to be equally mortal in all classes.

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[5] The bracketed interrogation mark after the words *de novo* in this paragraph is mine, as is that also in paragraph 8 following the word "generating."

12. Typhus and relapsing fever are strongly assimilated in the causes which give rise to them, if they be not mutually convertible diseases. Typhoid fever on the contrary appears to be a perfectly distinct affection dependent upon totally different causes.

It is very interesting to note that in the course of this paper Dr. Murchison observed "that out of 10 *cow-keepers* admitted with fever in nine the fever was typhoid," and also that he "ascertained that in several instances patients entered as 'labourers' had been *employed in the drains;* in every such case the fever was typhoid." Of the patients admitted to the fever hospital "most of those who may have been supposed to have occupied the best conditions have been admitted with typhoid fever. ...... Thus the proportion of family servants admitted with typhoid has been three times that of typhus, of policemen six times, and of shopmen more than double. On the other hand ...... among 'paupers' typhus and relapsing fever taken together have been eight times as frequent as typhoid, and of 64 'vagrants' admitted with fever in not a single instance was this typhoid." Again: "Typhus fever among the rich, except as the result of contagion, is excessively rare, while cases of typhoid originating without any traceable contagion are far from uncommon. ...... I think, then, it may be concluded that typhus and relapsing fever are for the most part confined to the poor, but that typhoid fever makes no distinctions between one class and another." He shows that typhus fever prevails in overcrowded localities, whereas "a careful study of a great number of recorded outbreaks of fever in country towns and villages throughout England has convinced me that these outbreaks are almost invariably typhoid. It is also a fact worthy of notice that several instances have come under my own observation of typhoid fever making its appearance in an isolated house in the country, in a family living in easy circumstances without any traceable source of contagion, of its attacking several individuals, and then disappearing without spreading beyond that house. Dr. Bartlett also makes similar observations as the results of his experience in America. On the other hand, I am acquainted with no instance of typhus or relapsing fever originating in this way." He agrees with Dr. Jenner that typhus fever and typhoid fever originate from *different foci of infection.* "In no single instance during the 10 years have I met with a case of typhus and typhoid admitted from the same family, or even from the same house except (and the exceptions have been only one or two) after the lapse of many months or even years." He then gives a number of cases in which typhoid fever was associated with "putrid emanations from decomposing organic matter in drains, cesspools, churchyards, &c., and organic impurities in drinking-water." These cases (actually dating from 1747 onwards) included the celebrated outbreak in the Westminster School and Abbey Cloisters in 1848, known as the

Westminster fever, which attacked 38 persons, all of the better class, with three fatal cases. A very bad smell had been complained of in the houses where these cases occurred during two or three days of very hot weather and "it was found that the disease followed very exactly in its course the line of a foul and neglected sewer in which fæcal matter had been accumulating for years without any exit and which communicated by direct openings with the drains of all the houses in which it occurred." He also relates that towards the end of 1852 an outbreak of typhoid fever took place at Croydon, which was investigated by a committee of the Epidemiological Society consisting of Dr. A. P. Stewart, Dr. Jenner, and Dr. Sankey, and which was found to be caused by fæcal emanations of various kinds and also by contamination of the drinking water. And as the end of this evidence he concludes "that typhoid fever is often, if not always, generated by the putrid emanations from drains and other sources, or by decomposing organic matter in drinking-water." While, then, Dr. Jenner proved that typhus fever and typhoid fever must proceed from different causes, Dr. Murchison took us a step further and showed in the most masterly manner that typhoid fever was not produced under circumstances of overcrowding as it was well known that typhus fever was, but that although spread partly by direct contagion it was chiefly spread by means of foul emanations from sewers and drains and the pollution of drinking-water with foul organic matters.

In 1862 Dr. Murchison issued his "Treatise on the Continued Fevers of Great Britain," and in 1873 the second edition of it appeared. In this work he gives an excellent historical account of typhoid fever which he calls enteric or pythogenic fever, the last name being suggested by him as an expression of what he believed to be the origin of the disease. This is shown in his opening lines wherein he defines it as "an endemic disease generated and propagated by certain forms of decomposing organic matter." This treatise is so well known that I need not summarise it. I will merely give his own summary of its etiology, which is as follows:—

> 1. Enteric fever is either an endemic disease or its epidemics are circumscribed. 2. It is most prevalent in autumn and after hot weather. 3. It is independent of overcrowding and attacks rich and poor indiscriminately. 4. It may be generated independently of a previous case by fermentation of fæcal and perhaps other forms of organic matter. 5. It may be communicated by the sick to persons in health, but even then the poison is not, like that of small-pox, given off from the body in a virulent form, but is developed by the decomposition of the excreta after their discharge. 6. Consequently an outbreak of enteric fever implies poisoning of air, drinking-water, or other ingesta with decomposing excrement.

With regard to No. 1, I will note that typhoid fever epidemics are often very widely spread. Nos. 2 and 3 are universally admitted and I will say no more about them.

Nos. 4, 5, and 6 imply the view so strongly held by Dr. Murchison that the disease is caused by a poison produced by decomposing fæces, which poison is not contained in the fresh excrement, and therefore amount to a denial of the fact that the disease is produced by an organism which is transmitted from one case to another. This view, like that of M. Gaultier de Claubry (who proclaimed the identity of typhus and typhoid fever) in France, obtained a great hold on the medical profession in this country and has been with considerable difficulty eradicated.

As to the incubation period of typhoid fever, Dr. Murchison stated his conclusions in 1871 in a paper which appeared in Vol. II. of the St. Thomas's Hospital Reports, page 23, as follows:

"1. The period of incubation of enteric fever is most commonly about two weeks.

"2. Instances of a longer duration appear to be more common than in typhus or relapsing fever.

"3. The period of incubation is often less than two weeks, and, as in typhus and relapsing fever, it may not exceed one or two days."

The usual period of incubation is now generally agreed to be from 11 to 14 or 15 days (see pages 41 and 45), but may be longer. Nevertheless, I believe that the instances of very long incubation periods are due to the fact that the effective exposure to the poison of the disease has taken place at a later date than the supposed exposure.

With regard to the very short incubation periods referred to in Dr. Murchison's third conclusion, I think that they are accounted for either in the manner suggested by Drs. Brouardel and Thoinot in their treatise on "La Fievre Typhoïde" (Paris, 1895), page 206, viz., that they are not genuine cases of typhoid fever, or that the effective exposure to the poison has really taken place at an earlier date than that given.

In 1873 Dr. William Budd produced his work on "Typhoid Fever, its Nature, Mode of Spreading, and Prevention," in which he maintains that *it was proved long ago* that "typhoid fever is in its essence a contagious or self-propagating fever,' and he adds, "It is scarcely to the credit of the medical profession that this great truth should still be disputed." He then quotes a number of authors who did dispute it, but mentions "Sir Thomas Watson who in his admirable work on the Practice of Medicine has not only lent his powerful sanction" to the doctrines of the contagious origin and mode of spread of typhoid fever, "but has given an exposition of them in that terse and lucid style of which he is so great a master," and I may add that in Sir Thomas Watson's small work on the "Abolition of Zymotic Diseases," published in 1879, he says, referring to typhoid fever, "When we reflect how readily this origin of the disease (through water or milk) may escape suspicion, or may elude detection even when suspicion has been roused, we find continual reason for distrusting the argument for the spontaneous development of the disease based upon the difficulty of tracing the contagion to any conceivable source. For my own part I cannot but deem this argument altogether worthless." In his work Dr. Budd proves up to the hilt that the disease is directly contagious or communicable from one person to another, and he gives the most remarkable examples of infection by direct contagion. As to this being one of the contagious fevers he well says: "The existence here, as in the other contagious fevers, of a latent period after the occurrence of the infection, the exemption conferred by one attack against any future attack, and, lastly, the immunity of large numbers of persons who though freely exposed to the fever poison yet remained proof against it, are characteristics of which the significance cannot be doubtful." He gives a graphic comparison between small-pox and typhoid fever. Each has a latent period; in each one attack protects against any future attack in the vast majority of instances, "so that if typhoid fever happens only once in life it is, as in small-pox, simply because the typhoid fever poison *cannot grow again* in a body in which it has once bred," and after pointing out that what we actually *see* in small-pox takes place in the diseases of the same group, including typhoid fever, he sums up: "*The living human body, therefore, is the soil in which this specific poison breeds and multiplies, and that most specific of processes which constitutes the fever itself is the process by which the multiplication is effected.* As in small-pox, so in typhoid—to spread by this mode of reproduction is not only a characteristic but the *master*-fact in its history." For him, "*all* the emanations from the sick are in a certain degree infectious. At the same time it is one of the principal objects of this work to show that what is cast off from the intestines is incomparably more virulent than anything else." Outbreaks of typhoid fever such as he describes, according to his view, "never occur except under one condition—that is to say, where no sufficient provisions have been made for preventing the discharges from the human intestine from contaminating the soil and air of the invaded area. Where these provisions are wanting the most spacious rooms and the freest internal ventilation afford no certain security against the spread of the fever." Finally: "Like malignant cholera, dysentery, yellow fever, and others that might be named, this is one of the great group of diseases *which infect the ground*. Hence the quasi-miasmatic character attaching to them all, which has misled so many observers as to their true mode of spreading."

It is not too much to say that in this admirable treatise Dr. Budd proves his contention up to the hilt, sufficiently, at any rate, to convince the highly-trained scientific mind of Professor Tyndall who, in a powerful letter to the *Times* dated Nov. 6th, 1874, referring to one of the outbreaks described by Dr. Budd, says: "How could a disease whose characteristics are so severely demonstrable have ever been imagined to be non-contagious? How could such a doctrine be followed out, as it has been to the destruction of human life?"

In March, 1874, I read a paper before the Epidemiological Society "On the Alleged Spontaneous Production of the Poison of Enteric Fever," from which I may be allowed to make the following quotations :—

> We are, however, told that the intestinal discharges from a patient suffering from enteric fever are not infectious when fresh and only become so after decomposition has set in, and in proof of this it is advanced that medical attendants do not take it from the patients, that nurses do not get it, and that other patients in the same ward, although using the same utensils, scarcely ever take the disease. Now it must be admitted that such cases are uncommon, though they are by no means unknown; indeed, I find that while Murchison, on page 461 of the second edition of his "Treatise on Continued Fevers," says, "I have never known or heard of a case where the fever has been communicated to the medical attendant not residing in the infected house," he says (p. 469) of Putegnat, who thought he had caught it from making a post mortem on a case, "It is true that he was seized a few days after the autopsy, *but he had attended both the patient and her mother during their illness*"; so that on one page we are told that the fever is not communicable because medical men do not get it from their patients, and 10 pages farther on we find that the fact that a medical man got it after making an autopsy is considered to be no proof that the body was contagious, because he had been attending the patient and her mother during their illness.
>
> But is it proved in any sense of the word that the fresh fæces of a patient do not contain the poison of the disease? Certainly not. All that can be deduced from the facts is that they do not give out the poison in any considerable quantities into the air, and this makes it probable, without reasoning from mere analogy, that the poison consists, like the active principle of vaccinia, of solid particles, which do not evaporate from liquids in which they are, but may be carried up mechanically by the volumes of gas given off when such liquids ferment, or after the evaporation of the liquid may be desiccated and blown about; thus we see how it may be that the fæces have come to be regarded as more poisonous when decomposing than when fresh, or even as developing the poison during decomposition.
>
> I say that there is not one iota of proof that the fresh stools do not contain the poison of the disease, and that to say so is like saying that a solution of sugar of lead or of corrosive sublimate, scented with, say, attar of roses, is not poisonous, because you can stay in the same room with it without being poisoned, or that a vessel of vaccine matter does not contain the active principle of vaccinia, because you can handle it without being affected by vaccinia.
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> I can understand the position taken up by Andral who "declared that he had never seen it exhibit the slightest contagious character"; or by Dr. Stewart who wrote in 1840, "In no case, though questioned with the greatest care, either in Scotland or in the hospitals of Paris, have I ever found the disease referred to contagion."
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> I can understand that taken up by Trousseau, by Dr. Budd, and by others, who maintain that the disease is essentially contagious. But I cannot understand the anomalous, as it seems to me, position of those who in effect say, "Well, it's not a contagious disease, but as you've certainly brought forward some cases in which it appears to have been communicated from man to man, we must admit that occasionally it is contagious."
>
> That it is contagious, and most virulently so, I have not the slightest doubt; but I quite understand what those mean who say it is not: they mean that if you attend upon a patient suffering from enteric fever you are not likely to get it, while if you attend on one suffering

from typhus or scarlet fever you are very likely to do so, unless you have had the disease before; they do not consider that this fact is not due to a difference in the contagious nature of the disease but to a difference in the form in which the poison is excreted from the patient, most of it being in the one case given out into the air which the attendants breathe, while in the other most of it is swamped in a mass of liquid which is removed as soon as possible. Those accustomed to small-pox, scarlet fever, and the like, of course said that enteric fever was not contagious when it was first brought to their notice, and there is no doubt that it is, under ordinary circumstances, very slightly so in their limited sense of the word; but that is not what is meant by those who now deny that, except under certain circumstances, it is not communicable from one person to another.

When we point to undoubted instances where a person suffering from enteric fever has taken it into a place where it was before unknown, but in which it has spread from that person, it is at once admitted "that there are unequivocal cases of enteric fever propagated in the manner described," but we are told that "such occurrences are exceptional, and that *the number of cases where the disease is introduced into a new locality without spreading far exceeds that in which it is* propagated," which means that the expedients adopted to get rid of the excretal matters were, in the cases observed (probably chiefly in large towns), generally sufficient to ensure the immediate removal of the infected fæces from the premises in a short time.

But I would put the facts in another light and would say: We see in how many cases we can prevent this disease from spreading; we can almost always point out the reason why it spreads in a house or town when it does so, and we ought to prevent its spreading much more frequently than we do.

Are we, then, able to trace every case of enteric fever to a previous case? Certainly not; and it would be very wonderful if we could. When we consider that a person suffering from this disease may go about for weeks, leaving the poison in several different places every day; that he may go about his work until so prostrate that he goes to bed to die; that he may fall down dead from perforation of the intestines without the disease having been recognised; that the poison which he has left in so many different places may be distributed broadcast in water, milk, sewer air, or some other vehicle,—when we consider all these things, we may well wonder, not that we are often unable to trace the disease to infection from a previous case, but that we are so often able to do so. From the fact that we are able so frequently to point out the source whence the contagion has been derived, and to trace it to a previous case, we have at any rate a strong presumption in favour of the view that when isolated cases occur, and there appears to be no connexion with previous ones, the fact is that we are unable to trace any such connexion, and it is clear from the nature of the disease that this must very frequently be the case; and, moreover, we have no right to assume that we even yet know all the methods by which the poison of this disease may be conveyed. It is only comparatively recently that milk has been recognised as a vehicle of contagion, and there may be, and probably are, many other media of which we have not yet any knowledge, by which the poison is conveyed from place to place.

It is clear that in towns, large and small, where strangers are continually coming and going, and where commodities of various kinds are brought from outside, and houses are connected with public sewers, it is not merely "difficult," as Dr. Murchison says, but on the face of it *impossible*, "to exclude the possibility of contagion," and so we may dismiss such cases at once. But then it must be allowed that many instances are on record where outbreaks of this disease have occurred in isolated villages and country houses, and where every effort has failed to trace any importation of the poison. It will be found on reading the published accounts of such cases that the possibility of importation in a variety of ways has been overlooked. A great many of them are cases of schools or other places where a number of people are collected together. No number of such cases would be sufficient to warrant the assumption that the disease arose *de novo* in any one of them. In most of the other instances we find that old cesspools, stopped-up drains, &c., have been disturbed, or have drained into wells, or leaked into the basements of houses. How are we justified in assuming anything more than that the filth contained the poison of the disease? How can we pretend for a moment to say that we have excluded the possibility of its introduction into masses of excrement which have been going on accumulating perhaps for years? The thing is manifestly impossible. And when we consider how many persons—visitors, servants, and vagrants—go to and from "isolated country houses," and their premises (stable-yards, &c.), we shall be disposed to hesitate before saying that we have excluded all possibility of importation.

I must confess that these considerations prevent my accepting any of the cases on record as cases where non-importation has been proved, and I cannot therefore accept the dictum that the disease "may be generated independently of a previous case by fermentation of fæcal and perhaps other forms of organic matter." Were this true, would not the disease be much more prevalent? How is it that a house or town may be in a condition eminently suited for the existence of this fever, as shown by the fact that when a case is imported the disease spreads, and often becomes a severe epidemic, and yet no case is heard of there for many years, until the importation takes place? One town that I have already alluded to is a most filthy, overcrowded place; it has been several times decimated by cholera, but no enteric fever occurred there for many years, until one day a case was imported, and the disease spread like wildfire, showing that the conditions for its existence were most favourable; and such instances might easily be multiplied were it necessary. Besides, we know very well what disease sewer air causes—it causes diarrhœa. Over and over again have I seen whole households prostrated with diarrhœa, when air from a foul sewer has leaked into the house, or air from a blocked-up sewer or soil-pipe has found its way into the drinking-water cistern through the waste pipe and has fouled the water.

I therefore maintain that foul air contaminated by decomposing animal matters is capable of producing mere diarrhœa and that when it produces enteric fever it contains the poison of that disease, and that the arguments adduced to prove that this poison can be generated from such decomposing matters independently of a previous case of the disease are inadequate to do so; that in many of the cases where non-importation is supposed to have been all but proved it has not been even rendered a fair presumption, and therefore that in the present state of our knowledge we are not justified in saying that the disease ever arises *de novo.*

The correctness of the views maintained in the above paper has now been demonstrated by the discovery of the *bacillus typhosus.*

LECTURE II.

Delivered on Feb. 25th, 1902.

Mr. President and Gentlemen,—I shall not trouble you with any proofs of the predisposing causes of typhoid fever about which there is no dispute. For instance, sex appears to have no influence on the disease, while the predisposition to it is much influenced by age, most of the cases being, as already stated, under 30 years of age, and the highest percentage of cases during the quinquennial periods of life being from 15 to 19 years of age, when nearly 27 per cent. of the total cases occur. Nearly 50 per cent. of the cases occur between 15 and 25 years of age, and over 84 per cent. between five and 30 years of age. I find it stated in vol. xxxi. of the Reports on Sanitary Measures in India (for 1897-98) that: "As usual, young men and unacclimatised soldiers were the chief sufferers (from typhoid fever). Among those from 20 to 25 years of age the death-rate was 12·74 per 1000, against 9·52 in 1896; while among men between 25 and 30, and from 30 to 34, the mortality was 4·98 and 2·77 per 1000 respectively. Among men of less than one year's residence in India the death-rate from this fever was 18·50 per 1000, among men between one and two years 10·79, and among troops between five and ten years' service the rate was 2·98 per 1000." It is especially a disease of autumn and is known as the autumnal or fall fever in New England, but an important exception to this in the case of London will be mentioned in the next lecture. It is especially prevalent during dry and hot autumns and generally rare in cool and wet ones. On the other hand, outbreaks of it are not infrequently checked by heavy rainfall which washes the soil and also washes away accumulations of foul matter in the drains and sewers, although heavy rains, on the other hand, may wash such impurities into water used for drinking, as pointed out by the late Sir George Buchanan in his report on Festiniog in 1863. Overcrowding appears to have less influence on the spread of typhoid fever than it has on any of the other contagious fevers, owing to the fact, no doubt, that the disease appears to be less directly spread from person to person than the other diseases of its class. It is also generally agreed that the poison of the disease is chiefly spread, as pointed out by Dr. Murchison, by means of excretal refuse, but especially by pollution of drinking-water by such foul matters. In the early times in the investigation of the causes of this disease it was considered sufficient to show that a place where it prevailed had its water, air, or soil or any or all of them contaminated with excremental filth. Thus, in the third report of the medical officer of the Privy Council, published in 1860, outbreaks in Bedford, Bath, and Kingston-Deveril (Wilts), and Dronfield (Derbyshire), are reported on, and in all of them it is considered sufficient to show the state of things just mentioned. But the inspectors of the Privy Council, headed by Dr. Buchanan, and under the guidance of Mr. Simon, were very soon not satisfied with such investigations and adopted the plan of, as far as possible, tracking each outbreak to the special circumstances more particularly associated with it.

We will now consider a number of instances in which cases of outbreaks have been caused in this and other countries, beginning with those which have been connected with *general insanitary conditions*, and I shall, as far as possible, quote the actual words of the reporters, as that will make the information much more valuable than if I summarised the reports myself. In the sixth report (1863) of the medical officer of the Privy Council is a report by Dr. J. S. Bristowe on fever at Whitehaven. He satisfied himself that the cases were undoubtedly cases of typhoid fever. He came to the conclusion that the fever was spread by means of general filthy conditions. He says: "I have no hesitation in asserting that there is no English town with which I am acquainted where the sanitary circumstances (with one or two exceptions) of the inhabitants, and especially of the poor, are in a more disgraceful and degrading condition. The houses of the labouring population (more particularly in the central parts of the town) are crowded together in a way which is scarcely conceivable; the houses are for the most part dirty, dilapidated, and imperfectly (if at all) ventilated; they are overcrowded and the cellars are habitually let out as tenements; houses, courts, and even streets are without any privy accommodation and where privies are provided they are of the most objectionable kind and generally most objectionable as regards their situation; drainage scarcely exists." And it must be remembered that this is the opinion of a metropolitan medical officer of health. Under the heading "Causes of Fever" he says that the condition of things disclosed in the statement just made "amply accounts for the present epidemic of fever; indeed, it is difficult to suggest any measures for producing typhoid fever so likely to be efficient as those which have allowed Whitehaven to be degraded into its present filthy state."

In the seventh report of the medical officer of the Privy Council (1864) is a report by Dr. Bristowe on fever at Grantham. He states that it was "true typhoid or enteric fever." He shows that it was not caused by the water-supply because it was distributed amongst persons supplied from various sources, "so that if the fever has been due to any poisonous quality of water this poisonous quality must have been shared by the canal water, the conduit water, and the well water as well as by the water furnished by the company." And he considers filthy conditions to have been the cause of it and says: "Knowing well as we do that typhoid fever has been shown over and over again to arise from the effluvia of accumulated human excrement and that throughout the whole town of Grantham such effluvia have prevailed there remains, I think, scarcely a doubt that the disease must be attributed to this cause. The fact that the disease has prevailed chiefly among the better-off classes is, on the whole, confirmatory of this view, inasmuch as it is their houses chiefly which are connected with the imperfect sewers (and connected, too, by imperfect means) and it is mainly along the streets which they occupy that the principal sewers of the town pass with their (until recently) untrapped gully holes."

In the same volume is another report by Dr. Bristowe on an outbreak of typhoid fever at Debenham. He points out that the disease seems to have clung to the eastern portion of the village and especially to the houses *bordering on the pond* or in its immediate neighbourhood. It would seem, and is by no means improbable, that this stagnant receptacle for filth was pestiferous and the direct cause of the illness which prevailed.

Of the same date is a report by Dr. George Buchanan on the sanitary state of Bridport, of which he says: "In truth, scarcely one London district really reaches the fever death-rate of Bridport, for those which appear to exceed it are chiefly those in which the great metropolitan hospitals receiving fever are situated. With London City, with Clerkenwell, with Marylebone and St. Pancras, Bridport will not bear a moment's comparison as to its fever mortality; no, nor even with Holborn, or Bethnal Green, or St. Giles." He adds that the fever was, no doubt, typhoid. Dr. Buchanan puts down as the causes contaminated water from shallow wells, described in a local broadsheet as "looking yellow, tasting strongly, with a nice good drainy smell." And "the retention of decomposing ordure and refuse about the houses. *The air of the town is polluted seriously* and on a considerable scale."

Dr. Buchanan, in his remarkable report "On the results which have hitherto been gained in various parts of England by Works and Regulations designed to promote the Public Health," states the general result of his observations as regards typhoid fever as follows:—"Many of the public improvements have coincided with reduction of typhoid. Though not with absolute constancy, drying of the soil of a town and reduction in the crowding of houses have been followed by reduction of fever. Much more important appears to be the substitution of an ample supply of good water for a scanty and impure supply; other things being equal, the towns in which this substitution has been completed have made most improvement. Merthyr is a conspicuous instance of a town where, before any other important change had been made, typhoid fell to a notable extent as soon as inspection and cleansing were adopted. It is, however, the purification of atmosphere from decomposing organic matters that has been most uniformly followed by a fall in the prevalence of typhoid. And this has occurred equally whether the purification has been brought about by the abolition of cesspools or by drainage and drying 'middens.'" (Ninth Report of the Medical Officer of the Privy Council, 1866).

In the tenth report of the medical officer of the Privy Council (1867) is an account of an investigation of an outbreak of epidemic typhoid fever at Winterton in Lincolnshire by Dr. Thorne Thorne. Of this he says: "The epidemic prevalence of fever in Winterton is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells," and he describes these in detail. He also gives an account of the water in the well supplying some of the cottages where there have been cases of disease and says that the people living in one cottage "and who have always enjoyed good health, not liking the taste of it, have drawn their water from a neighbour's well." On this he remarks: "Nothing could point much more conclusively to the contaminated state of this water, and on examining it I found it to be of a light brown colour and disagreeable taste and to yield a considerable deposit after standing for a few hours. Under the microscope it exhibits a large quantity of organic matter, both animal and vegetable, as well as infusoria and animals of a low type." Dr. Thorne made an attempt to ascertain how the fever originated and on this he says: "In some instances I endeavoured to ascertain whether the fever could have had a spontaneous origin, but the inhabitants all seem to be on such terms of intimacy with each other that they continually frequent the infected houses, there assist in attending to the sick, and thus come into contact with the bowel discharges, or else they drink the contaminated water. My inquiries therefore failed to elicit any information on this subject, and owing to the fever having now existed in the town to a greater or less extent for nearly seven years I was unable to ascertain the manner in which it first originated."

Mr. J. Simon in his Report as medical officer of the Privy Council and Local Government Board for 1873 (New Series, No. 2) gives in an appendix "Illustrations from Inspectors' Reports of the four years 1870–73, of the circumstances in which enteric fever is commonly found prevalent." There were 148 such reports during the four years.

Dr. F. R. Blaxall reports on Selborne, Hants: "Outbreak of enteric fever following importation to the village of a case of that disease, subsequently spread by polluted water and infected privies. Water-supply derived from wells which are much exposed to pollution, filthy privies, neglect of excrement removal, general want of drainage." (Ninth report of the medical officer of the Local Government Board for 1879.)

Slaughter-houses have sometimes been suspected to be in some way or other the cause of the spread of typhoid fever in their neighbourhood, but when investigated these cases have always been found to be explained by some other cause. For instance, at New Brighton (Cheshire) in 1888 there were complaints respecting an alleged occurrence of typhoid fever round a certain slaughter-house. Mr. Spear reported that the fever was not more common in New Brighton than in other parts of the urban district of Wallasey, but that the tendency to the recurrence of the disease was in the low-lying part of the district, especially in certain spots, one being in the neighbourhood of the particular slaughter-house. He, however, stated that "there is not sufficient evidence for regarding the slaughter-house as the origin of the fever prevalence," but that the fever was "due in all probability to the condition of public sewerage and private drainage which in the low-lying area, and especially as regarded the houses invaded, was found to be remarkably defective." Mr. Spear reported in 1890 that at Runcorn (Lancashire), where typhoid fever had been epidemic in 1884, 1887, and 1889, the spread of the disease was "associated with excremental contamination of the air by large deep ill-placed midden privies believed to have received bowel discharges of antecedent cases of the disease." In 1891 Dr. R. Richmond, medical officer of health, traced an outbreak at Hatfield Broad Oak to water from the town pump which was polluted by "the saturation of the soil with offensive matter from the want of sufficient drainage in the village, the multitude and bad construction of the cesspits and the improper disposal of house refuse" as "no drains or sewers are in the vicinity of the town pump." (*Public Health*, vol. iv.) In 1894 Dr. R. Bruce Low reported on an outbreak in the borough of Widnes (Lancashire) where there had been a continued presence of the disease for a series of years. There was evidence of importation at times from the adjacent town of Runcorn, but the spread of the disease in Widnes was "associated with fouling of air near dwellings by emanations from large privy middens in which are stored collections of excrement and other filth under very unfavourable conditions. Surface of unmade roads near the houses gradually filled by midden excrement every time the privies are emptied. No evidence of spread of disease in Widnes recently by contaminated milk, polluted water, or sewer air."

We now come to outbreaks attributed to *polluted water*. In the sixth report of the medical officer of the Privy Council (1863) is a report by Dr. Buchanan on Fever at Festiniog. He reports that it was typhoid fever, and with regard to the water he says: "The water-supply for some domestic purposes is obtained from the stream in the valley. This water is exposed to constant contamination ; but it was stated positively, and with remarkable accord, that it was never under any circumstances employed for drinking. Water for internal use is got from wells on the mountain side, presumably situate above any possible source of pollution. Only at Bethania (one of the villages of the Festiniog Union) was there much reason to believe that a drinking-water had got contaminated by drainage." He, however, adds in a note : "Though it was very positively stated by numbers of persons that they never drank the water of the streams it is difficult to feel sure that a strict separation would be made in their use if two sorts of water were admitted into a house." He was very evidently of opinion that overcrowding had a good deal to do with the spreading of the fever, for he says, "The fever has been most prevalent and severe in the crowded houses. Some mild cases have also occurred in clean cottages, not overcrowded. But few cases have occurred in the barracks."

In the seventh report of the medical officer of the Privy Council (1864) is a report by Dr. H. J. Hunter on fever at Harpenden. He says : "The disease was plainly typhoid with diarrhœa" and he distinctly attributes the cause of it to drinking-water. In describing the house where the first case occurred he says : "The well, with a rotten structure of timber above it, was in the garden ; and five or six yards from it, and raised two feet higher, was a brimful cesspool. Visitors to Bosher had complained of the water and a supply from another well had been got for them ; but the family habitually used their own well until a few weeks ago, when they abandoned it because the rottenness of the edge made it dangerous to approach near enough to raise a full bucket. This well, like the others in the neighbourhood, pierced through a bed of gravel to reach the chalk and the cesspool by its side was in the gravel." Of the house where the next case occurred he says : "But in this case, as in Bosher's, the family had been obliged to desert their own well after bearing with its horrors too long a time. The well was not only in a filthy yard, unprotected, near drains and cesspools, but the people who lived nearest to it were, in general terms, accused of dirty habits injurious to the water." And with regard to another village where the fever prevailed he says : "The first four houses in the list adjoined and being one property used one privy and were supplied by one well which had a greater degree of nastiness than the rest and which was spontaneously abandoned by the consumers soon after the fever appeared. Lying low in the filthy yard it was visible that it received the surface drainage, besides what might result from inward filtration....It is worthy of observation that the earlier cases were the drinkers of this water and that amongst them only of this group was there mortality, also that they seemed to have an instinct of one at least among the causes of their illness and sought a change of water, with some apparent success." There was, however, it will be noticed, no attempt to prove that the poison of typhoid fever had in any way obtained access to the water, it being then sufficient to prove that the water was contaminated with sewage.

In the tenth report of the medical officer of the Privy Council (1867) is a report by Dr. Buchanan on an outbreak of typhoid fever at Guildford, of which Sir John Simon says that the epidemic of typhoid fever at Guildford was peculiarly instructive and adds: "The distribution of the disease, especially during the first fortnight of the epidemic, so nearly corresponded in area with a particular section of the public water-supply of the town as to raise the strongest suspicions that this section of the water-supply was at fault. And eventually these suspicions became a certainty. First, namely, it was shown that on one particular day in August (about 10 days before the beginning of the outbreak) 330 of the 1675 houses of Guildford had *exceptionally* received their water from a certain high-service reservoir which had been previously filled from a new well and that the persons residing in or frequenting these 330 houses constituted the part of the population on which the epidemic influence had almost exclusively fallen. Subsequent chemical examination of the water of the new well detected in it the products of organic decomposition and examination of the local circumstances showed but too unquestionably whence the decomposing organic matter had been derived. The new well, no one could doubt, was most dangerously situated: in the porous and fissured chalk stratum, it was within 10 feet of various sewers, one of which, indeed, was traversed as a short cut by the iron delivery pipe of the high service. And when after the epidemic this reckless confusion of sewer and waterworks was dissected the state of things found at the spot was reported to us in the following terms by Mr. Taylor, one of the Poor-law medical officers of the town: 'The engineers employed in the repairs of the steam-engine noticed some exudation on the wall of the engine-house next the valley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage the ground was opened in the valley at a point adjacent to the engine-house. The sewer was found leaking in various places and the soil between it and the wall of the engine-house was saturated with sewage, of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain constructed with red, unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away and at one point several feet of them were missing and the upper tiles had fallen in upon the soil below. All the joints gave exit to water and the ground was a quagmire of filth beneath and on each side. Dark-coloured fœtid slush had to be dug out and removed in baskets, making the men vomit who were employed in the work.' There, of course, could not be any reasonable doubt but that the passage of this filth into the well, from which the high-service reservoir was filled, had been the cause of the epidemic."

In his report on this outbreak Dr. Buchanan makes a very interesting observation with regard to the period of incubation of typhoid fever as follows: "A point in the natural history of typhoid appears to receive elucidation if the deductions of this report as to causation are correct. The water which is believed to have been the 'cause' of the outbreak was delivered on August 17th and on that day only. The first cases of the fever came under medical observation on August 28th; after that two or three each day and a very large number on Sept. 3rd and 4th. With allowance for the varying time that would elapse in various cases between the occurrence of the first symptoms of typhoid and the sending for a doctor there is enough correspondence in these dates to fix the occurrence of the first symptoms in a great proportion of cases on or about August 28th, or 11 days after the operation of the cause. Inasmuch as other cases occurred in considerable numbers for several days after Sept. 4th it may be that in those cases there was a longer incubation period. This does not, however, upon such information as is available, appear to have been necessarily the case, for many of the high-service houses are furnished with cisterns and others with large underground tanks in which the water received on August 17th would be stored; mixed, indeed, more or less with other water delivered before and after, but not necessarily losing any noxious quality it might have possessed until a considerable number of days had elapsed. The houses in Pannell's-terrace were attacked particularly early and suddenly. These have no cisterns but take their water direct from the mains."

In his twelfth report as medical officer of the Privy Council (1869) Sir John Simon says: "Among the circumstances which we find associated with outbreaks of typhoid fever there is none of more frequent occurrence, none which we are more entitled to consider directly causative of the disease than *the consumption of polluted water*. It has been one of our most familiar experiences, one which my reports for many years past have again and again been obliged to exhibit in all its nauseous details, and which in the present report receives a new and striking illustration, that excremental fouling of wells is, in this respect, among the worst dangers which can threaten the health of a community; and it might be assumed that other common water-supplies, as distributed by companies and local boards, would equally be capable of spreading the infection." He then cites the Guildford case (already described) as an apt illustration. In the same volume is a report by Dr. Buchanan on an outbreak at Wicken Bonant, Essex. "There were, among persons getting water from private wells, less sources, "so that if the fever has been due to any poisonous quality of water this poisonous quality must have been shared by the canal water, the conduit water, and the well water as well as by the water furnished by the company." And he considers filthy conditions to have been the cause of it and says: "Knowing well as we do that typhoid fever has been shown over and over again to arise from the effluvia of accumulated human excrement and that throughout the whole town of Grantham such effluvia have prevailed there remains, I think, scarcely a doubt that the disease must be attributed to this cause. The fact that the disease has prevailed chiefly among the better-off classes is, on the whole, confirmatory of this view, inasmuch as it is their houses chiefly which are connected with the imperfect sewers (and connected, too, by imperfect means) and it is mainly along the streets which they occupy that the principal sewers of the town pass with their (until recently) untrapped gully holes."

In the same volume is another report by Dr. Bristowe on an outbreak of typhoid fever at Debenham. He points out that the disease seems to have clung to the eastern portion of the village and especially to the houses *bordering on the pond* or in its immediate neighbourhood. It would seem, and is by no means improbable, that this stagnant receptacle for filth was pestiferous and the direct cause of the illness which prevailed.

Of the same date is a report by Dr. George Buchanan on the sanitary state of Bridport, of which he says: "In truth, scarcely one London district really reaches the fever death-rate of Bridport, for those which appear to exceed it are chiefly those in which the great metropolitan hospitals receiving fever are situated. With London City, with Clerkenwell, with Marylebone and St. Pancras, Bridport will not bear a moment's comparison as to its fever mortality; no, nor even with Holborn, or Bethnal Green, or St. Giles." He adds that the fever was, no doubt, typhoid. Dr. Buchanan puts down as the causes contaminated water from shallow wells, described in a local broadsheet as "looking yellow, tasting strongly, with a nice good drainy smell." And "the retention of decomposing ordure and refuse about the houses. *The air of the town is polluted seriously* and on a considerable scale."

Dr. Buchanan, in his remarkable report "On the results which have hitherto been gained in various parts of England by Works and Regulations designed to promote the Public Health," states the general result of his observations as regards typhoid fever as follows:—"Many of the public improvements have coincided with reduction of typhoid. Though not with absolute constancy, drying of the soil of a town and reduction in the crowding of houses have been followed by reduction of fever. Much more important appears to be the substitution of an ample supply of good water for a scanty and impure supply; other things being equal, the judgment, to say that in my opinion Clark's fever somehow or another was caused by the fever imported from London."

Typhoid fever has been very frequently spread by *contaminated water from shallow wells.* Other instances of this are the following. In 1873 I traced a severe outbreak of typhoid fever at Market-Weighton (Yorks) to the well of the hotel in which I was staying. More than one member of the landlord's family had had the disease and the privy was situated close to the well. In Stone (Staffs.) Dr. Edward Ballard reported in 1874 that there was a constant prevalence of enteric fever, and that among other causes was the following: "Wells sunk close to cesspits and drain openings. Privies and wells specifically polluted by the excremental discharges of the sick."

In the Twelfth Report of the medical officer to the Local Government Board for 1882 is an account of a localised outbreak of typhoid fever at Norwood, in the Uxbridge Rural Sanitary District, by Mr. W. H. Power (now the chief medical officer of the Local Government Board). The cause of this outbreak was so clearly traced by Mr. Power and is of such great interest that I may perhaps be excused for giving his account almost *in extenso*: "Very early in the investigation it was noted that the suddenness, the intensity, and the impartiality of the incidence of the outbreak best accorded with what is known of enteric fever epidemics caused by specifically infected water or milk. Milk causation of this outbreak had for good reason to be set aside, while as regards its possible causation by water there appeared at first sight a serious difficulty. The 14 houses invaded in the upper part of the terrace are provided with three pumps, each of which, it was affirmed, sucked from a separate well, and hence there appeared to be required for explanation of the outbreak by water causation sudden and simultaneous infectiveness of the water of three separate wells many yards distant from one another and from the houses. This seemed a highly improbable occurrence, and thus some time was spent over the cesspool air hypothesis, until the great difficulties in explaining the attacks of inmates of house No. 13 (which is on a separate system of cesspools) furnished a clue of much value. *It was found that pump No. III.* which served houses Nos. 13, 14, 15, 16, 17, and 18 *had at the date of the outbreak been for a long time out of order*, and as a consequence the inmates of these houses had for many weeks before their illness sought for water elsewhere. Naturally they resorted to the pump most accessible, *which happened to be pump No. II.*, for pumps No. IV. and No. I., which also they could have used, were cut off from them, the one by a strong fence, the other by a brick wall. Thus it came to be seen that at the time of the outbreak all the houses invaded had been for many weeks getting their water-supply from *one or other of two* *instead of from three pumps as had been confidently stated.* This reduction in the number of pumps, and therefore of wells implicated, did not, however, greatly help towards belief in water-causation of the outbreak, for there seemed well-nigh as much difficulty in accepting sudden and simultaneous infection of two as of three wells. In this dilemma I sought to ascertain whether pump No. II. had not for some reason or other come into temporary and exceptional use shortly before the occurrence of the outbreak by the inmates of houses 23 to 30. But this suspicion had to be abandoned. Both pumps had been in good order throughout the period in question, and pump No. I., which is separated from pump No. II. by a brick wall, had been used, and solely used, by the inmates of houses 23 to 30, all of which houses had been invaded in the outbreak. Still I was unable to accept a hypothesis of sudden and simultaneous infection of two widely separate wells far distant from the houses and from the cesspools—rather I was disposed to regard the confident local assurance respecting pumps Nos. I. and II. sucking from separate and distinct wells as open to doubt, and thus *it came about that I announced that for complete belief in water causation of the outbreak it was necessary that pumps No. I. and II. should suck from a single well.* My surmise was quickly put to the proof by Mr. Freeman, the inspector of nuisances, with the result—a great surprise to certain inhabitants of the terrace—that the suction pipes of Nos. I. and II. were found to lead to one and the same well.

Here, then, in infectiousness of a particular well water is explanation in some sort of the outbreak. It accounts for the limitation of the outbreak to the particular part of the terrace comprising houses 13 to 30 as well as for the intensity of the fever incidence on these houses. But it does not explain all the facts. There remains to be accounted for the two months' interval between the August–September series of cases and the outbreak of December, and especially does the suddenness of the outbreak when it did occur require explanation.

At an early stage of suspicion as to water causation of the outbreak and upon assumption of conservation in the cesspools of enteric fever material derived from the first series of cases with subsequent soakage thence of this material through 60 or 70 feet of soil to two or more wells, the above facts did not appear easy of explanation. But no sooner was a particular well found to be alone in question than a clue appeared that had been wanting. For thus considered it was seen that suddenness of the outbreak *almost necessarily implied sudden infectiveness of the particular well*, such as might have resulted from fresh conditions newly brought to bear on it, and on it alone; and search in this direction now revealed the following facts. *On Nov. 27th,* 1881, cesspool cleansing was commenced in the terrace and was repeated on subsequent days up to early December; *and* *the cleansing proceedings included transference of the contents of these cesspools to a hole newly dug in the garden some 40 feet from, on higher ground than, and in the line of natural soakage to, the particular well which has been called in question.* Now the main outburst of the fever did not occur until the second week of December, soon after the commencement of this cesspool emptying. Then, be it observed, and not till then, did any notable extension of fever in the terrace take place, and this notwithstanding that the cesspools must be regarded as having fostered ever since August material presumably capable of causing enteric fever. The inference is not to be avoided—namely, that this exceptional transference of cesspool contents to a hole in the ground near the particular well speedily brought about specific pollution of the well water, and thus occasioned the sudden outbreak of enteric fever among persons using that well water.

Certain subordinate considerations remain to be noticed. They do not affect the above conclusions, though they may have interest for the etiologist. Allowing for the incubation period ordinarily observed in enteric fever, this outbreak followed very quickly on the procedure which is believed to have fouled the well. It would seem, therefore, that either highly potent infective matter transferred from the cesspools to the soil of the garden passed at once into the well; or, in this particular outbreak, the interval of time between the occasion of infection and the first symptom of illness was in many persons abnormally shortened. Shortening of the incubation time may no doubt have occurred. In would be in accord with experience of certain milk outbreaks of enteric fever where consumers of large amounts of the implicated milk in a raw state have seemed to suffer from fever within a very few days of their infective meal. And what is true of enteric fever conveyed by milk may be true also of enteric fever conveyed by water, for in both instances there is chance of infective matter of great potency getting applied directly and in abundance to the intestinal tract. In this outbreak there was in many cases the usual difficulty in exactly fixing the date of attack, but so far as I have been able to ascertain by personal inquiry case by case the early attacks occurred as follows :—

Doubtfully on or about Dec. 4th, seven days after commencement of emptying of cesspools	1 case.
In three days, Dec. 8th to 10th, 11 to 13 days after commencement of emptying of cesspools	12 cases.
In three days, Dec. 11th to 13th, 13 to 17 days after commencement of emptying of cesspools	5 ,,

The above facts are not, it will be observed, inconsistent with shortening of the incubation period, as regards the earlier cases, though abridgement of that period is not absolutely requisite for their explanation.

Upon the whole, I am indisposed to accept such explanation, believing rather that infective matter passed *directly to the well on, or within a few hours of, the 27th November*, and for the following reasons. The freshly dug hole in the garden to which cesspool contents commenced to be transferred on Nov. 27th was situate, as has been said, some 40 feet from the particular well, upon higher ground, and in the line of natural soakage to the well. No doubt, therefore, the relative positions of the cesspool deposit-hole and the well, *and the porous character of the gravelly soil intervening between them*, were physical circumstances conducive to *rapid passage of cesspool-derived liquid from the newly made hole to the well—though the interval of 40 feet* that had to be traversed by this liquid in getting to the well seems at first sight to almost forbid belief in fouling in this way of the well within a few hours of commencement of cesspool emptying. But there are other circumstances to be taken into account before a decision is arrived at. *The hole freshly made in the garden for the reception of cesspool contents was dug against a wall that runs toward and within three or four feet of the particular well, and nearly midway between this hole and the well the suction pipe of pump No. II. passes immediately beneath the foundation of the wall on its way to the well.* It cannot be doubted that we have here special facilities for rapid passage of foul fluid from the recently removed cesspool contents to the particular well. Fluid matters poured against the wall would travel towards lower ground most readily and quickly along the foundation of this wall and could be thus led in the direction of the well; and, further, upon reaching a spot nearly midway between this starting-point and the well, such liquid matters could gain access to the trench in which the suction pipe of pump No. 2 had originally been laid, and following this new course alongside that pipe would be conducted directly into the well. Whether or not the above was the course actually taken by foul liquid matters soaking from the cesspool deposit hole to the well cannot now be determined. Mr. Freeman sought to put this surmise also to the test, but he failed for the reason that the plumber who had meanwhile been employed in laying on the Norwood Water Company's supply to the terrace had removed the suction pipes of the wells. In removing the suction-pipe of pump No. 2 the interval of ground between the cesspool deposit-hole and the well had become so greatly disturbed that trustworthy evidence on the above point was not to be had."

In 1883 Mr. W. H. Power made an important report on an outbreak at Hitchin on which Dr. Buchanan makes the following remarks in his report as chief medical officer: "In a report by Mr. Power on an epidemic prevalence of enteric fever at Hitchin fresh illustration is given of the now well-known fact that the distribution of enteric fever often follows, both in place and time, the distribution of impure water in such a way that the water cannot but be regarded as conveying the material of the fever. The particular interest of the Hitchin outbreak arises from the circumstances that it was the water-supply of the sanitary authority which had become thus infected and that the impurity, certainly connected (as Mr. Power's report shows) with the fever, yet had not been anywise recognised as the cause of the fever until his inquiry. In these respects and knowing the ability of cholera to be conveyed by water in the same manner as enteric fever, the case of Hitchin is of particular value to the present report." Mr. Power states that "the public water supply is derived from the Bath spring, situated at Charlton, half a mile south of the centre of the town. This spring arising in the chalk flows into an underground chamber adjoining a cottage built against the hill side. From the chamber the water of the spring is led by iron pipes through a neighbouring spinney (supplemented at intervals between the iron pipes in its course from several additional springs coming to the surface therein) across the Hiz into Priory Park. From this point the water conduit, now consisting of clay-socketted earthenware pipes, is conveyed into the town by way of Bridge-street, and, recrossing the Hiz again by iron pipes, finally discharges into receiving tanks in connexion with the pumping well which is situated close to the river in Queen-street."

The water had generally been considered to be not only sufficient in quantity but unobjectionable in quality.

"But from the story that has been told respecting the method of conveyance of the water to the town there is obvious suggestion of many chances of pollution encountered by it on its way thither, and it cannot, therefore, be regarded as uniformly a safe supply. Formerly risks of pollution of the water were even more abundant than at present, and it needs to be said that the existence of such risks has not been disregarded by the Sanitary Authority. Within the last few years certain privies belonging to the houses at or near to the Bath spring have been removed to a distance from it, and their vaults have been made watertight. Earthenware pipes, too, that at one time conveyed the water through the spinney have been replaced by iron pipes, and inspection holes on the conduit in the spinney, which at one time were left open, have been fitted with heavy stone covers. Some other and serious risks to the water that still remain may be particularised as follows:—The cottage at the spring is occupied by a laundress, whose cellar-kitchen, used by her as a wash-house, is within a few feet of, and at a higher level than, the underground chamber containing the spring. Consequently there is, in the event of this woman washing clothing or linen fouled by enteric fever discharges, risk of specifically contaminated laundry water soaking through the imperfectly drained floor of her cellar-kitchen into the spring itself. Again, the spinney, where are the minor springs coming to the surface and supplementing the public supply, is not securely fenced against trespassers, and as a result the ground here was, on my visit, observed to be littered by human excrement. Further, the clay-socketted earthenware conduit between the spinney and the pumping well may not be relied on for safe conveyance of the town water. Within the limits of the Priory Park it permits perhaps nothing worse than addition of soil-water to the public supply; but in its course through the town this conduit comes in relation with a variety of sewers and drains, some of which are very possibly defective, and here, therefore, there is risk of the conduit taking up, along with soil water, dangerously foul matters that have been exuded from drains. At the point, too, in Bridge-street where the conduit crosses the Hiz, similar risk to the town water-supply is not wholly averted by substitution of iron for earthenware pipes. This iron conduit, which is not less than 30 years old, may be seen partly exposed in the bed of the river, and a junction in the pipe towards the centre of the stream has every appearance of having become corroded. Finally, even on its arrival at the pumping station, the town water has been by no means safe from dangerous pollution, as will presently appear."

"The public water-supply of Hitchin having come thus under suspicion, the facts already recorded as showing various risks to the water on its passage to the service reservoir appeared of graver import, and now an additional and exceptional risk to the water, not as yet defined, demanded especial consideration. This further opportunity for pollution of the public water-supply consisted in the circumstance that at the pumping station an eight-inch overflow pipe, contrived to convey surplus water from the receiving tank and pumping well into the river Hiz, permitted on occasion reflux of the river water into the tank. Discovery of this defect in January last was not only startling but was in a way satisfactory to the sanitary authority, for it went far to explain a difficulty that had for some time troubled persons concerned with the waterworks—viz., that without obvious cause, suddenly and at uncertain intervals, the water in the pumping well had been apt to become turbid. Along with identification of the cause of this occasional turbidity of the water service came recognition also that coincidence of two separate conditions was requisite for back flow of the river into the tank. These were slight rise in the level of the water in the river and a reduction by pumping operations of the level of the water in the tank and pumping-well to the extent of arresting overflow to the river from the tank through the overflow pipe. How often in times past these conditions have been coincident it is impossible to say, since the occasions of turbidity of the water-supply have not been recorded. But in the winter just passed, under circumstances of admittedly exceptional liability of the river to flood, and with modification last November of the routine of the engine-man's labours bringing about a doubling on pumping days of the hours of pumping, opportunities for coincidence of the conditions requisite for pollution of the pumping-well have seemingly been more frequent, and unquestionably during this winter turbidity of the water in the pumping-well has occurred on several occasions. The defect of the overflow pipe here noted was, it should be stated, rectified on Jan. 13th, since which no further turbidity of the water-supply has been observed. It would perhaps be difficult to over-estimate the gravity of the above defect in the water-service apparatus. For the Hiz, which in its course through the town is hardly more than a ditch a few feet in width, receives refuse matter cast into it from poorer dwellings abutting on it, and the river water, therefore, is liable to contain some of the most dangerous qualities of sewage. On one occasion of cursory inspection of the river I myself observed littered on the edge of the stream, just above the point of entrance to it of the overflow pipe from the water-works and ready to be carried there by the first rise in level of the river, diarrhœal excrements cast out from the back windows of dwellings on its banks. It would seem, therefore, that given the existence of enteric fever in Hitchin and the not rare chance of excrement from fever patients getting into the river, with the liability of the river water to on occasion supplement the public water-supply, there should be no difficulty, if the water service has really been in fault, in getting some more precise explanation of the epidemic diffusion of the fever in the town than has yet been afforded. Accordingly I sought to ascertain whether or not—having regard to a two weeks' interval (or thereabouts) such as usually elapses with enteric fever between the occasion of infection of an individual and the first beginning of his illness—there had been any observed occasions of turbidity of the public water-supply that could have been related to outbursts of fever in the town. There was, however, difficulty in ascertaining this, for, as has been mentioned, no record has been kept at Hitchin of the occasions of turbidity of the water service. In the end I was able to fix the date of one only of such occasions, arriving at it in the following fashion. The outburst of fever in mid-January, which was most recent, and the facts about it most likely therefore to be remembered, was taken as a test case, so to speak, of ability of the water service to spread fever, and information was sought as to turbidity of the town water two weeks previously—viz., about the end of December—with the following result. On the afternoon of Saturday, Dec. 30th, a day on which a heavy rainfall of 0·67 inches was registered in Hitchin, very general complaint had, it turned out, been made to the waterworks manager that the water delivered by the public mains was thick or turbid; and examination forthwith undertaken by the water-works people revealed the fact that the water in the pumping-well and in the service reservoir also was in like condition. Seemingly, it was the amount on this occasion of turbidity and its close sequence on the rainstorm that raised among the people concerned about the waterworks suspicion as to its

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origin and which led eventually to detection of the offending overflow pipe. Now, so far as I could learn, the water in the Hiz on Dec. 30th, rose suddenly and rapidly, and it could at once have passed back, and in considerable volume, through the overflow pipe into the pumping-well, for in view of the storage of water necessary for Sunday's consumption pumping operations had by 4 P.M. on Saturday lasted nine hours, thus reducing to a comparatively low level the 'spring water' in the pumping-well, and leaving the pipe intended to conduct surplus water from the pumping-well into the river to serve as a conduit for backflow of river water into the pumping-well. In the face of the above evidence it is impossible not to admit that in all probability there has been direct relation between the circumstances of pollution on Dec. 30th of the public water service and the outburst of fever in mid-January. As to the outburst in mid-December, however, like causation may not, in the absence of like positive evidence, be quite so confidently affirmed. But looking to the very similar behaviour of the two outbursts, and to the other evidence that has been adduced tending to convict the water service as responsible for the observed distribution of the fever, it is easy to credit for this, the first outbreak, similar direct relation to the public water service. And in this connexion may be noted some facts or coincidences that are interesting, though not perhaps worthy to be classed as evidence. In regard to both outbursts there were matters connected with the water-supply that, on a hypothesis of water causation, might have been concerned on each occasion with the otherwise unexplained rapid declination and sudden termination of the outburst. As regards the second, or January, outburst, discovery of the defaulting overflow-pipe and arrest in mid-January of this source of pollution of the public water service was followed some two weeks later by sudden cessation of the fever, and similarly complete emptying and thorough cleansing on Dec. 14th of the storage or service reservoir (which, for the purpose of the present hypothesis, may be regarded as having been the storage reservoir of fever material also) was followed again in about two weeks by well-nigh complete disappearance of all fever that can be considered as related to any common cause of the December outburst."

In 1884 Dr. David Page reported on an outbreak at Beverley (Yorkshire). The water-supply was chiefly from borings into the chalk which were occasionally found to be polluted by defective drains in their neighbourhood (there were 185 houses supplied by a private waterworks company); other sanitary defects; an outbreak of typhoid fever occurred in July, 1884, consisting of 231 cases in 125 households; the main feature of it was that the general water-supply of the waterworks company derived from a deep well in the chalk was specifically contaminated, the company's well and reservoir being in immediate contiguity to a sewage irrigated field belonging to the East Riding County Lunatic Asylum, in which cases of typhoid fever had occurred before the outbreak in Beverley.

In 1889 Dr. J. Ashburton Thompson, chief medical inspector of the Board of Health of New South Wales, issued a report on an outbreak of typhoid fever at Balranald which he traced to pollution of water in a certain tank which was supplied with rain-water and was sunk in the marly clay and not known to be puddled outside; near it were several cesspits. It was shown that 14 households, in all 124 persons, were supplied with this water, and an analysis of the cases in those 14 households in which that water was regularly drunk, in comparison with that of households the people of which are not known to have drunk it, gave the result that of 124 persons who regularly drank the water 34 per cent. suffered; while of 476 persons whose relation to the water cannot be defined (that is, who were not known to have drunk it) only 5·2 per cent. suffered.

I am indebted to my friend Professor Brouardel, for many years Doyen of the Faculty of Medicine of Paris, for the particulars of three outbreaks of typhoid fever which he investigated and reported on in 1887. The first occurred at Pierrefonds. In August and September, 1886, 24 persons from Paris and Versailles went to live in three adjoining houses at Pierrefonds; 20 of these persons contracted typhoid fever more or less severely, and four of them died. It was ascertained that cases of enteric fever had occurred in these houses before, one of them having been visited five times by this fever between 1874 and 1883. The water-supply in the houses on both sides of the street was from wells which communicated with one another through the very porous soil. This was proved by the fact that a few years before a fruiterer who kept one of the houses on the other side of the street let fall a can of oil into his well, and three or four days afterwards the oil appeared in the well of one of the houses in question. The subsoil water supplying these wells passed either alongside of, or below, the cesspools of the different houses. These cesspools were not watertight, being constructed of small stones without any cement. One of them, with which two of the infected houses were connected, had a small drain from its lower part discharging into the neighbouring stream. This drain at the time of inspection was blocked, the cesspool had not been emptied for 30 years, and it was almost full of hard deposit which had to be removed with a spade. The wells for the two houses were dug at distances of 9 and 20 metres respectively from this cesspool and in such a position that the level of the bottom of the cesspool was a little above that of the surface of the water in the wells. To increase the danger the rain-water from the roofs was also discharged into the cesspool, so that whenever there was a heavy shower the water washed the fæcal matters into the subsoil and thence into the wells.

A specially interesting observation was made with regard to the dates of attack. In one house five persons out of seven were attacked, all on August 27th or 28th. In another seven persons out of nine were attacked between Sept. 17th and 22nd except one domestic who was attacked on Sept. 10th, whereas in the third house all the members of the family were attacked between Sept. 25th and 28th, so that each family was attacked at a different time, but all the members of one family were attacked at about the same time. Dr. Brouardel points out an interesting explanation of this in the fact that there were heavy rains on August 2nd, 22nd, 23rd, and 24th, and Sept. 3rd, and that the attacks at these three houses were in each case about from 20 to 25 days after these rains. He also adds that the difference in the distance of the wells from the cesspools no doubt had some relation with the difference of the dates of the attacks. Samples of water from these wells were bacteriologically examined by Dr. Chantemesse, the director of the Bacteriological Laboratory at the Faculty of Medicine of Paris, and by M. Widal, and they obtained from one of them (a month after the outbreak of the disease) cultivations of the Eberth-Gaffky bacillus which they identified by comparison with cultivations obtained from the blood of the spleen of a person suffering from typhoid fever. The water was also chemically examined but it was found that the organic matters in solution in it had been almost completely oxidised. Of this Dr. Brouardel remarks: "This is an observation of which the importance is easily understood in the discussion of the question of the purification by the soil of sewage water charged with excremental matters. It shows that the soil destroys organic matters which come in contact with it; they undergo nitrification in it; but it is not the same for the germs of typhoid fever. They persist a long time in the earth; they lived for more than a month in the water of one of the wells of Pierrefonds." He then goes on to show that a case of enteric fever had been imported from Paris into one of those houses at Pierrefonds at a remote period. As is very usual in such cases the intensity of the disease varied very much among the persons attacked. Of this Dr. Brouardel says: "Of 24 persons 20 were attacked. Of these four died; six recovered after a well-characterised attack of typhoid fever; six others suffered from *états fébriles typhiques*; two others from short attacks called *embarras gastriques*, apparently not specific; and two had violent attacks of fever. The character of these different manifestations only obtains its true significance because they were simultaneously developed among the same surroundings." "If these morbid conditions had not burst out in the same focus their nosologic value would certainly have been misunderstood." On this point he quotes P. Lorain, "De la Température du Corps Humain et de ses Variations dans les Divers Maladies." "Perhaps there is a *typhoidette* as there is a *varioloid*. There is no reason why one should not admit this hypothesis, but it is a hypothesis." Of this Dr. Brouardel says: "That which Lorain considered as a hypothesis seems to me to-day absolutely proved, and I demand that one should admit in nosology this name of *typhoidette* which has the great advantage of recalling, more than the names actually used, the source from which some of these gastro-intestinal conditions originate." Dr. Brouardel then attacks the interesting question of immunity and asks whether these mild forms of the fever infection afford a relative immunity from a fresh attack of the disease. "Does the *typhoidette* differ from typhoid fever as the varioloid does from variola?" He considers that it does so and that it is to this cause that we must assign the relative immunity which the inhabitants of countries often visited by typhoid fever enjoy, and I may add here that this very fact has been observed among the Boers during the present war.

Among instances of the *pollution of the water of deep wells* are the following. In 1879 (ninth report of the medical officer of the Local Government Board) is a report by Dr. Thorne Thorne of an outbreak of typhoid fever at Caterham and Redhill which Dr. Buchanan summarised as follows: "(*b*) Dr. Thorne's investigation of a strongly-marked outbreak of enteric fever at Caterham and Redhill resulted in conclusive proof of the manner of its distribution and was of singular interest as demonstrating how limited a quantity of infective material may suffice under favouring circumstances to do widespread mischief. In one of the wells of the local water company a new adit was being formed and among the workmen was one who during his occupation in the adit suffered from a slight attack, at the time unrecognised, of enteric fever. He, when pressed by diarrhœa, used for his relief a bucket that was provided for raising to the surface the chalk dug from his workplace underground. It was found to be certain that the well-water could thus have become contaminated and there was no suggested way of its contamination by any other means. For the rest, quite satisfactory evidence connected the supply of water from this well with the prevailing epidemic that extended beyond Caterham to Redhill and other localities supplied by the company's water."

In 1889 Dr. Gresswell reported on the prevalence of typhoid fever at Cradley (Worcestershire). He traced the disease to water from a particular well in the sandstone, near which there was an old brick and mortar culvert receiving drainage of houses, while only 20 yards from the further end of a heading in the well and on ground rising somewhat steeply therefrom there was the churchyard. He showed that the defective culvert had received enteric fever discharges and that no doubt by leakage from it the well became infected. (Nineteenth report of the medical officer of the Local Government Board.)

In 1889 Dr. David Page reported on an outbreak of typhoid fever at Houghton-le-Spring (Durham), the cause of which is of exceptional interest. He traced the epidemic to the water of a well or staple sunk to a depth of 330 feet into sandstone strata of the coal measures, and the investigation is of such importance that I quote at length from the end of the report: "In looking around beyond the immediate vicinity of the well for possible opportunities of contamination I had visited early in my inquiry the farmhouse of Herrington Hill. This is situated about three-quarters of a mile to the south of Herrington Colliery on rising ground and about 150 feet above the level of the surface of the well. The farmhouse and buildings are upon the magnesian limestone, the beds of which dip towards the north. Owing to subsidences caused by the colliery workings below fissures extending to the surface exist in this locality. The drainage of the farm buildings, of a cottage, and of the farmhouse itself (in which latter there is a water-closet) is conveyed to a tank. The overflow from this tank escapes and disappears down an adjoining fissure in the ground. To determine whether a connexion existed between this fissure (three-quarters of a mile from the well) at Herrington Hill farm and the water-bearing strata supplying the 'staple' I suggested that common salt should be dissolved and thrown down the fissure. Instructions were given to this effect and two tons of salt were accordingly thrown down on May 11th. At this date the discovery of the 'feeder' in the 'staple' had not been made and testing of the water as pumped from the well did not give any conclusive indication of increase of chlorides. On the discovery of the 'feeder' a week later a clue to the excess of chlorides shown by it (as compared with the body of water in the well) was apparently furnished and, as will presently appear, the source of the chlorides was in the end conclusively demonstrated. From May 24th a series of daily testings of the relative amounts of chlorine in the water of the reservoir and of the 'feeder' were made. The chlorine in the water of the reservoir varied from 2·3 to 2·8 grains per gallon. On May 29th, with a view of placing beyond doubt whether the increase of chlorine thus shown was due to the salt thrown down the crevice at Herrington Hill, five tons of salt were washed down the crevice with a hose-pipe running for twelve hours, during which time it was estimated that some 100 tons of water were discharged. On the following day the chlorine present in the water of the 'feeder' rose to 15 grains per gallon. The testing was continued for a few days longer and on June 5th the chlorine reached the maximum amount of 24 grains per gallon. During the next few days it fell again to the former amount. The connexion between the two localities, the farm tank and the 'staple,' was thus conclusively established and the source of excremental contamination of the water-supply demonstrated. Specific contamination of the sewage from the farmhouse could not, however, be made out, no illness of a character resembling enteric fever having been known to occur at the farm during recent years. It remains to add that since the discovery of the 'feeder' arrangements had been made by Mr. Lishman for the supply to the affected district of water for drinking purposes from wholesome sources. Warnings had been issued to the people against resorting to the tap-water for drinking purposes and it was further decided to abandon the Herrington water as a source for domestic supply. To meet the immediate exigencies of the case and to guard against danger from a continued distribution of this water the Houghton service was turned on and distributed through the Herrington mains for two hours night and morning. But as this supply was insufficient to meet the requirements of the whole of the district arrangements were made and actually carried out for boiling the supply pumped from the Herrington well before it entered the reservoir. Engine boilers, which were fortunately at hand, were erected and adapted to this purpose, and on June 2nd these arrangements were completed and in operation. On the occasion of my final visit to the district on June 7th I witnessed the remarkable and unique instance of the delivery to the mains of a water-supply which had been actually submitted to a boiling temperature." To fill the water mains of a town with water which had been all boiled was indeed a remarkable and unique experience.

Dr. Theodore Thomson reported in 1893 on an extensive outbreak which occurred in the Borough of Worthing (Sussex), where there were no less than 1317 cases with 168 deaths. Of the cases 1257 were in Worthing proper and 58 in West Worthing. The villages of West Tarring and Broadwater were also invaded by the disease. This epidemic was found not to be referable to general sanitary circumstances, to sewerage or drainage, or to milk-supply. The epidemic in Worthing and Broadwater, which have a common water-supply, was shown to be caused by water from a new heading which was contaminated by foul matter from leaky sewers, and this water was shown by bacteriological examination to contain not only abundance of the bacterium coli but also bacillus typhosus itself. The epidemic in West Worthing and West Tarring which were provided with another water-supply appears to have been due to local infection of the water mains.

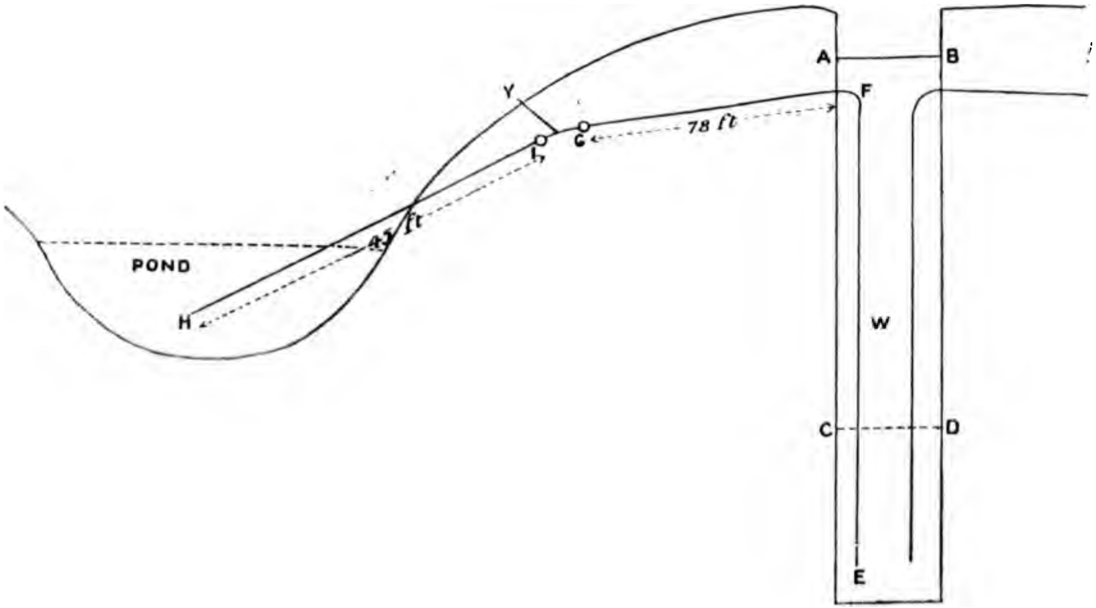
In 1894 Dr. Thomson also reported on simultaneous outbreaks of typhoid fever and of fever of less definite sort at various places in the Borough of Newport, Isle of Wight. He found that these outbreaks were referable to a public water-supply common to all the invaded places. This water-supply was derived from a well in the chalk at Carisbrook and was found to be open to dangerous contamination from the leaky drains of houses near the waterworks and standing on the chalk, and also from a filthy mill-pond. There was, moreover, serious risk of dangerous pollution of the water in the deeper strata of the chalk supplying the wells, from the existence of numerous cesspools within the area drawn upon by the two wells.

In 1895 Dr. Bruce Low reported on an epidemic of typhoid fever at Raunds (Northamptonshire). There were two distinct groups of cases, each group being "associated with use of water from a different public well that had become specifically polluted. The closing of these two wells, one after the other, was followed by a marked subsidence of the outbreak."

A most interesting and remarkable case of the pollution of a deep well water has come under my notice recently. In a large country house where there had been a case of typhoid fever I found that the main sewer leaked badly into the land drains of the park. A number of these land drains discharged into a pond in the park. The well from which the house was supplied was near to this pond but the pond was watertight and did not leak into it. The well water was generally very good. This well water was pumped to tanks in the mansion, but the same engine and pump also drew water from the pond in question and forced it through another main to the garden, the suction pipes from the well and from the pond meeting in a junction-chamber where there was a stop-cock on each, so that when the stop-cock on one was shut the pump drew from the other. Between the junction-chamber and the pump there was only one suction-pipe, so that the water from the well and from the pond had to pass through this common suction-pipe to get to the pump. The engineer stated that before pumping well water to the mansion he always pumped some of it to the garden in order to wash the common suction-pipe and the pump, but I nevertheless ascertained that when water was being pumped to the house on certain occasions, one of which I observed myself, a very foul smell was forced into the cistern-room and the water was sometimes turbid. The explanation of this is no doubt as follows. The water in the well stands as a rule considerably higher than that in the pond, so that there cannot be any direct communication between them, or the water in the well would leak away down to the level of that in the pond, which is not the case. When, however, the level of the well water has been considerably reduced by pumping, as is frequently the case, if it so happens that both of the stop-cocks are left open, the two suction-pipes must act as a siphon and the water from the pond be sucked over into the well, and there can be no doubt that the water in the well has not been infrequently contaminated in this way. (See Diagram.)

My friend Dr. Pistor of Berlin has kindly sent me two reports on polluted well waters. One by Dr. Mewius of Cosel (Silesia), on an outbreak of typhoid fever which occurred in that town in October, 1899, and was traced to the use of polluted water from the well of one of the hotels in the town[1]; and the other by Dr. Bloch of Beuthen (Silesia) on

[1] Zeitschrift für Medizinalbeamte, Heft 19, 1901.



When the water level in the well W is at A—B, if the valves G and I are open water runs from the well by pipe E, F, H into the pond, but if the water level is lower than that in the pond, as at C- - -D, and both valves are left open, the suction-pipe and pump Y being sound, the water in the pond would be siphoned into the well.

a serious outbreak of the same disease which took place in that town from June to October, 1897, and was traced to the pollution of the town supply by excremental matters from the mines which filtered through the soil into the wells of the public water-supply after a heavy flood which swamped the mines and washed the fæcal matters out of the pails in the mines before they could be removed.[2]

My friend Professor Kuborn, M.D., of Seraing, Liège, the President of the Royal Society of Public Health of Belgium, has kindly forwarded me a number of reports to the Minister of Agriculture by the provincial medical commissions of that country, from which I find that the spread of typhoid fever there is due (Report for 1891) "for many places to the pollution of the water-supplies, for some to importation and to direct contagion ; in these the relations of cause and effect are precise. Lastly, in a more vague sort of manner overcrowding, moisture, and want of cleanliness are alleged causes." That it is due to polluted well-water is not to be surprised at considering that the following is given as a description of the wells supplying the working classes in one of the great towns : "A well surrounded with privies, heaps of manure, and goat-stables furnishes water to all the inhabitants. These come there to obtain the water with vessels which have served for all sorts of purposes. Most of the inhabitants are workpeople employed in the city—a fact which explains the rapid spread of the disease." In another report we are informed that while the water is at fault in some places in others "it is the houses which are at fault, whether by overcrowding or by filth."

In Luxembourg I find from the report of works carried out during 1892 an account of an outbreak at Marcour, "which has for the last 15 years had a public water-supply and which during that time has not been visited by typhoid fever, but the water-supply to the inhabitants was completely spoilt on account of the drought which had laid dry the open end of one of the main pipes drawing water from a stream ; various animals having found their way into this pipe died there and the decomposition of their bodies polluted the whole of the water-supply. As soon as this cause of pollution was withdrawn a stop was put to the epidemic. And in another place called Bastogne, where there had not been a single case of fever since 1887, when the public water-supply was established, "the drought having diminished the quantity of water available, the communal authority allowed resort to be made to old wells, recommending the people by placards not to use the water for drinking. But a certain number of the inhabitants took no notice of this warning ; 20 days after the reopening of the wells there were 30 cases of typhoid fever ; a month later 100 cases, of whom 10 died."

Again, in the report for 1893 we are told that "in the great majority of cases it has been possible to trace the origin of the disease and the causes of the same, which were found almost always indicated. The most frequent by far consists in the pollution of the drinking water due to the defective construction of wells, the filtration of organic matters through their walls, the mixture of spring or river waters with waste waters in a state of putrefaction, of manure deposited on the fields or in the proximity of houses, especially after heavy rains have washed the country, cleansed the streets, and made the cesspits and the water-courses overflow. Next to this came the importation of the disease by individuals, most frequently workmen coming home from an infected locality; direct contagion operating habitually between persons of the same family or living together in small apartments; emanations from foul sewers; and the want of disinfection of the stools of typhoid patients." In the report for 1900 I find it stated that "sometimes typhoid fever is also spread by means of the bad habit which farmers have of throwing typhoid excreta on the dung-heaps. It has resulted that in the spring while spreading the manure on the fields the workmen who had carted the winter manure were infected by the bacilli which had been deposited in the autumn. The manure in preserving its temperature, its humidity, and also certain salts and albuminoids, supplies them with an excellent cultivating medium."

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[2] Deutsche Vierteljahrschrift, 1898

Water-supplies have sometimes been shown to be *polluted at or near their springs* by infiltration into them of excremental matter, and outbreaks of typhoid fever have taken place when such matter is specifically polluted. Among these are the following.

Bricksworth (Northamptonshire).—Dr. Thorne in 1874 reported that this fever was habitually prevalent and that the water was liable to surface and excremental pollution.

Dr. Hubert Airy reported on an outbreak of enteric fever at Blackburn in Lancashire in 1881 as follows: "This water-supply of Blackburn runs the risk of pollution at its several sources. There is risk at the gathering ground above Pickup Bank; there is risk at the White Birk colliery of some accident similar to that which befell the Caterham well; and there is risk at the well on Revidge, for houses are pretty numerous round about and the soil is a porous sandstone rock. Moreover, as regards the water from Pickup Bank there is risk at very many points along the route by which it is conveyed to the town. The stone culvert ...... is of rough construction, built of the ragstone of the district in rude wedge-shaped lumps, fitted together without mortar or cement, but well bedded in thick puddle; and remembering that this culvert has lain for more than 30 years, only three or four feet deep, on the slope of the hillside, with a constant tendency to increase of pressure on the upper side, and lessening of pressure on the lower side, it can hardly be [illegible] Shorrock's-row [illegible]

After describing how he found a place where water was leaking into the culvert he continues:—"In opening the ground at a corresponding point in the pasture above the men struck upon an old stone land drain which was then traced some distance back and appeared to run obliquely across the meadow from the upper side. Approaching the culvert it ran within nine yards of the last of a row of privy pits which lay outside the bounding wall of the back yards of Shorrock's-row, accessible from the meadow, for the convenience of the farmer who took the manure. The farmer assured me that he spread this manure only on the land below the culvert, never above, but there were signs of the overflow from the privy pits having been conducted on to the pasture above the culvert. The impression left upon my mind, though I could not positively prove the fact, was that there was a probability of soakage from these privy pits and from the slop gutter in front of Shorrock's-row affecting the purity of the water in the culvert. I have dwelt somewhat at length on these dangerous conditions along the line of the conduit because I shall have to show that the chief outbreak of enteric fever in Blackburn followed close upon, and possibly was caused by, the occurrence of enteric fever at Belthorn and Shorrock's-row. The water on leaving the culvert, just within the wall of the reservoir enclosure, runs in an open enclosure for 20 or 30 yards before discharging into the reservoir. An empty can or two lying in this channel showed that it was exposed to casual additions and I noticed just within the gate of the enclosure and immediately over the mouth of the culvert the remains of human ordure. In the side of the open channel is a gate-sluice which, when desired, can be set open so as to divert the stream, or part of it, into an open by-channel which runs down between the Guide embankment and the public road and is finally turned into the lower (Fishmoor) reservoir. In its course it receives the contents of a ditch which, when traced back, is found to take origin at the back of some dwellings in the upper part of Guide village, whence it comes along a cartway trodden and befouled by cattle, past a farm-yard, and through a field, exposed in its whole length to the risk of pollution. I heard tales also of mischievous fellows throwing 'nast' (filth) into the reservoirs themselves. The six-foot enclosure wall is easily climbed."

Dr. Airy then shows how one of the privies had been shortly before the outbreak infected by the stools of a man, Aspden, who had typhoid fever and goes on to say: "This case was not visited by the medical officer of health nor by the inspector of nuisances; the danger to the public health *attending the presence of a case of enteric fever so near the main artery of the water-supply was overlooked.* An unskilled labourer who works under the nuisance inspector was sent to the house with some carbolic acid powder. Aspden states that this disinfectant was used to discharges which were then thrown into the privy, one of the row of privies that have their pits opening to the meadow through which the water-culvert passes. Slops and rinsings of vessels undisinfected were thrown down a sink in the backyard or thrown into the roadside gutter in front of the house. Either channel would carry them, as already described, immediately over the water-culvert, at points where it was evident on internal examination that fluid was in the habit of oozing into the culvert. Any such admixture, supposing it to occur, would be infinitesimal in comparison with the quantity of water flowing in the culvert, and that again, in comparison with the whole body of water in the reservoir which received it, would be but as a river flowing into the sea. It certainly taxes the imagination to suppose that so minute a portion of infected matter would suffice to give a poisonous taint to so large a body of water, unless it possessed the property of self-multiplication." (Eleventh report of the medical officer of the Local Government Board, 1881.)

The second report, for which I have to thank Dr.

Brouardel, was on an outbreak which took place at Clermont-Ferrand, prevailed from September to December, 1886, and was investigated by himself and Dr. Chantemesse. This outbreak was "more severe and more generally spread in the southern portion of the town which includes the best quarters." There were two separate outbreaks, not only at Clermont-Ferrand but at Mont-Ferrand, towns two kilometres apart. These outbreaks "had the same course in the two towns and their maximum height was almost on the same days." On the other hand, the outbreak did not attack Royat and Chamalières, two little towns equally near to Clermont-Ferrand, yet the explanation was found in the fact that Clermont-Ferrand and Mont-Ferrand are supplied with the same water, while Royat and Chamalières have each a separate and independent source of supply. It was observed that the persons in the two infected towns who drank only boiled water or mineral water were not attacked, and that in a convent at Clermont-Ferrand supplied by a special fountain in its park there was only one case of typhoid fever and that occurred in the case of a person who had visited her parents and had drunk of the town water-supply. The first outbreak appears to have been caused as follows. In August a woman suffering from typhoid fever lodged in a villa at 35 metres from the water conduit; the cesspool of the house was not watertight and there was a washhouse which discharged its water into a stream passing over the water conduit, but the landlord stated that the visitors' washing was done in the public laundry at Royat, close to which was a water conduit for Clermont-Ferrand, the pipes of which were "made of earthenware in such bad condition that eight days after our inspection at the end of December the municipality of Clermont has thoroughly replaced the earthenware pipes by iron ones." 20 days afterwards typhoid fever broke out in the town, appearing in nearly all quarters at once. The second outbreak, on the other hand, appears to have been caused by the excretal matters of two typhoid fever patients having been thrown out in the street in the month of October "on this soil of lava cracked with fissures of 20 to 25 metres in depth *either at the point where the water of Clermont is obtained or close to it.*" The second outbreak took place at Clermont-Ferrand and at Mont-Ferrand at the beginning of November and especially towards the middle of the month. The typhoid bacillus was found in the water in the cistern of a house where there had been typhoid fever during the second outbreak. This cistern had not been cleaned for two years and a young girl who drank water from it had an attack of typhoid fever.

The third report, kindly forwarded me by Dr. Brouardel, was on an investigation made by himself and Dr. Chantemesse in 1887 into some outbreaks of the disease in the barracks of the Marines at Lorient. They reported that although the fever raged among the troops the civil population remained almost intact, while during the cholera epidemic in 1866 the population was attacked and the soldiers almost all escaped. It appears that the inhabitants of Lorient and the troops drank water coming from two different places. The causes of the outbreak were stated to be as follows: "The principal cause is the intermittent infection of the drinking-water; the secondary cause is defective installation of the latrines in the barracks. It appears that the excremental matters of the town are collected in moveable pails in which they are carried outside the town and spread upon the fields as manure twice a year, in the beginning of February and during August. This is regularly done by the farmer of the fields, under the surface of which the waters which supply the arsenal collect. The springs under these fields are produced by the rain-water which falls on the neighbouring hills and in the valley above the fields. Sometimes the level of the underground water which forms the spring is only separated from the surface of the soil by a bed of pebbles of a few centimetres in thickness. These waters, which at their point of collection are already polluted, arrive at the arsenal in old pipes which are not watertight. The principal conduit traverses the subsoil of heavily manured meadows and of the garden of the hospital on which the excreta of all the patients are constantly being thrown. In the passage of this conduit across that garden the conditions are such that it is not possible that the drinking-water should not be sometimes polluted. The secondary cause of propagation of the fever is the infection of the air due to the installation of latrines which are mere wooden tubs placed immediately under the windows of the barrack-rooms. As soon as these latrines are infected by typhoid excreta they can spread around the germs of the disease. On the first and second floor of the barracks one window is more particularly situated immediately above the tubs; the three beds placed by the side of this window on the first and second floors have been occupied by soldiers who have all been attacked with typhoid fever. Around them in the same messes of the barracks the victims of the disease were much more widely separated. Thus twice a year human excrement is thrown upon the meadows where the source of water which supplies the barracks of the arsenal springs and twice a year an epidemic of typhoid fever bursts forth. The manuring takes place first in January and February and then in August; the epidemics appear in March and in October or November. The rain is the bond which closely unites these two facts, the manuring of the land and the explosion of typhoid fever." Further proof, if any were necessary, is to be found in the fact that "for some time past in order that the recruits may avoid the dangers of living in the barracks of the arsenal they have been made to encamp on their arrival at the 'Polygone de Lorient' supplied by the town water. While typhoid fever has raged in the arsenal at its ordinary periods there has no tbeen a single case of it among the recruits."

At Rotherham (Yorkshire) and two adjoining districts typhoid fever and "fever of a less definite sort" was again prevalent in 1891–92, and Dr. Theodore Thomson reported that it was "not due to sewerage or drainage, nor to excrement disposal, nor to milk-supply, but to a public water-supply common to the invaded parts of each district" and to the high-level section of it, which section was shown to have been similarly related to fever prevalence in previous years. In a subsequent report Dr. Thomson shows that this water was contaminated by being collected from gathering grounds which "contained a great deal of cultivated ground which is manured not only with farmyard but also with privy midden refuse, and sewage from villages as well as from detached houses finds its way into the water-supply, more especially on the high-level gathering grounds."

In 1896 Dr. Bruce Low reported on an outbreak of fever at Penrhynside (Carnarvon). The nature of this disease was "at first obscure; some cases resembled typhus, others cerebro-spinal fever, and a few influenza; ultimately malady regarded as true enteric fever; infection imported. The water-supply was from an extension of the Llandudno water-mains. At the time of the outbreak the pipes were encrusted and partially blocked. There was no evidence of pollution of this public water-supply. The service was scanty and intermittent, "causing the villagers to seek temporary supplies from springs and spouts on slopes of hillside below village. Some of these temporary supplies were most probably polluted by washing of surface filth from village down the slopes by heavy rainfall; hence the spread of the disease."

In 1897 Dr. Bruce Low reported on an outbreak of typhoid fever in the Horsforth Urban District (Yorks.). He found that the gathering ground for the water company was high-lying pasture land dressed freely with stable manure and night-soil and that the sewage from farmhouses and also road washings reached the feeders of supply. "Sand filtration was provided, but in summer months as well as at other times it has been customary to turn on unfiltered compensation water to the town mains to augment supply. Following use in September, 1896, of this unfiltered water there occurred a sudden outbreak of enteric fever in October, attributed by the medical officer of health to polluted water of company's service."

In 1898 he also reported on a sudden outbreak of typhoid fever in December, 1899, in the town of Camborne (Cornwall) and an adjoining parish and village. The only condition common to these three places was their water-supply. "One of the two sources of this supply was from some springs at Boswyn, to augment which section of the supply a pipe had been laid from the brook to the service tank. The brook was *fed freely by surface water* from a hillside on which, in a cottage, four cases of enteric fever occurred in October and November, 1897. The bowel discharges of these cases reached a pond close to the house which had no privy. In wet weather the pond overflowed and the water from it ran down a channel to the brook, entering at about 100 yards above the intake pipe of the Camborne Company. In mid-November the rainfall was excessive and the flood-water washed out the pond and carried the pollution to the brook and thence to the service reservoir. After the removal of the pipe connecting the brook with the reservoir, and after cleansing the service tank and flushing the mains, the epidemic abruptly ceased."

In 1897 Mr. J. S. Davy, Dr. Theodore Thomson, and Mr. G. W. Willcocks were appointed by the Local Government Board to inquire into an epidemic of typhoid fever at Maidstone which Mr. M. A. Adams, the medical officer of health, believed to have been caused by the pollution of some of the springs supplying the water company's water by the excremental matters from a colony of hop-pickers. The arguments used by Professor Sims Woodhead and myself against this view were that there were cases of typhoid fever in Maidstone before the hop-pickers came at all, that many of the public sewers and house-drains and other sanitary appliances were in an extremely defective condition, so that contaminated air from them gained access to the houses, and that after the suspected water was cut off and a further period of 16 days allowed for incubation of any subsequent cases 357 more cases, which could not have been caused by the water, occurred in the town—a contention which the inspectors said was in their judgment "in the main a just one"—and that therefore the causes which operated to produce them might have produced the whole epidemic, a contention which the inspectors said "is probably in some degree admissible." Nevertheless, they came to the conclusion that the epidemic was caused "by the pollution of the water supplied by the Maidstone Company from their Farleigh sources."

I now come to instances of outbreaks of typhoid fever which have been traced to the pollution of streams and rivers supplying drinking-water. Early in the "seventies" I traced a severe outbreak of about 180 cases of typhoid fever which occurred in the fishing village of Mevagissey (Cornwall) to the contamination of the stream running through the village by the excreta of a typhoid fever patient who had come there during an early stage of the disease.

In 1882 Dr. F. W. Barry reported on an extensive outbreak of typhoid fever at Bangor and its neighbourhood. He showed that this outbreak was due to an "*extremely well-marked case of enteric fever of a severe type* which occurred at a place called Llwynrhandir. The medical officer of health directed the inmates to bury all excreta, &c., and this they promised to do. From information, however, obtained from credible witnesses," says Dr. Barry, "I am convinced that nothing of the kind was done until a considerably later period, when no doubt the discharges from this particular patient were buried in the garden. *The slops and washing water from this house are thrown into a sink at the back and pass by means of a covered rubble drain along the back of it and the house adjoining, where it discharges into a small rapid stream, which in its turn is conveyed as far as the boundary wall of the garden in a similar covered drain, and is thence conducted by means of an open ditch direct to the river Gaseg, into which it discharges at a point about 350 yards above the intake of the Bangor water-supply, the whole distance from the house to the intake being about 700 yards.* Upon removing some of the stone covers from a portion of the stream near the house a most offensive smell was perceived. The stream has an exceedingly rapid flow, so much so, indeed, that some whitewash which I poured into the sink behind the infected house could be traced for a considerable distance towards the Gaseg. It will thus be seen that there is a direct communication between the infected drain at Llwynrhandir and the small stream from which the Bangor water-supply is drawn and in this manner no doubt infected matter found its way into the filtering reservoir. The privy at Llwynrhandir is of the ordinary cesspool type; the pit is, however, below the level of the drain already referred to. As to the capability of the filtering material in the filtering beds at the waterworks for destroying or preventing the passage of infective matter we know little, and here the question need not be considered, because I found that from the presence of old defective plugs in the filters themselves fully a third of the water was passing direct into the watermain without any filtration whatever. The filtering sand has not been renewed for a great number of years, although I understand that it undergoes a certain amount of cleansing from time to time. I was further informed by the clerk to the urban sanitary authority, who is also the waterworks manager, that from the peaty character of the water the filters frequently become clogged, and at such time the water cannot be filtered rapidly enough to meet the demand, hence the water is passed into the mains without any attempt whatever at filtration. Here, then, we have established a direct means of communication between the consumers of water and the specifically poisoned contents of a drain at Llwynrhandir; further, we have cases occurring simultaneously miles apart from one another which, with the exception of the water-supply, had no circumstances in common, there being also an entire absence of cases in houses not so supplied. I have, therefore, now no hesitation in attributing the primary spread of the disease to the water-supply."

After describing the course of the outbreak he concludes as follows: "Taking all the facts of the case into consideration, it is my opinion that the water-supply became specifically infected to a slight degree on or about May 22nd, and that this pollution continued until the end of June. That this continuous slight pollution accounts for the dropping nature of the cases up to July 7th. That the special outbreak in the second and third weeks of that month was due to the communication of infected matter in a concentrated form owing to the disturbance in the reservoir and filter-beds, resulting from the accident to the main on June 30th. Finally, that a certain number of the cases which have occurred from the end of the first period to the present time are due to the direct introduction of infected air from the sewers into which the discharges from cases of enteric fever had been received." (Twelfth report of the medical officer to the Local Government Board for 1882.)

An outbreak at Mytholmroyd (Yorkshire) in 1888 was attributed by Dr. Page to pollution of the river Calder by the sewage of towns higher up its course.

In 1891 Dr. Hubert Airy prepared a most important and comprehensive report on the Outbreaks of Enteric Fever in the Valley of the River Tees in 1890–91, in which he showed that these outbreaks were especially amongst the users of water from the river for domestic purposes; thus "it was found that the rate of attack from enteric fever per 10,000 living during the first six weeks' epidemic had been 33 amongst persons supplied by the Tees water, and three amongst persons supplied with other water; whereas in the second six weeks' epidemic the rates were 28 and one respectively. Indeed, during the two periods together for every single person who contracted enteric fever amongst the population not using the Tees water 15 contracted it amongst those who were supplied from the river." This river was liable both habitually and still more during floods to fouling by human excreta and other filth from the town of Barnard Castle and some 20 villages and hamlets. Commenting on this the late Sir R. Thorne remarked: "Over a wide area covering 706,020 acres, or 1103 square miles, and containing 503,616 inhabitants, enteric fever has for years past been unduly prevalent. Within this area, where the infective material is thus constantly ready to hand, there occur in 10 sanitary districts, covering 117,404 acres, and containing a population of 217,363, two marked and sudden outbursts of enteric fever, each of large amount, the remaining area meanwhile exhibiting, as regards its constituent sanitary districts, comparatively insignificant 'fever' rates. One of the outbursts is at a time of year when, apart from some exceptional and unusual factor, enteric fever is not apt to prevail in epidemic form in this country. Within the sanitary districts invaded by the two epidemic prevalences some localities suffer heavily whilst others escape exceptional incidence to the disease. One factor alone is found to be common to the places thus suffering exceptionally from enteric fever and this is the use of water pumped from the river Tees. This river is found to be at all times subject to conditions of the grossest fouling by reason of the fact that human excreta and other filth are knowingly and deliberately conveyed to it. Opportunities for the access of the specific material of enteric fever to the river had been constantly recurring. And immediately antecedent to the epidemic outbursts sudden floods washed vast masses of the filth which had been accumulating on the banks of the river down the stream up to and past the points of intake from which the water was being pumped and, after filtration through sand and gravel, delivered to certain populations. These populations it was who suffered from the two exceptional prevalences of enteric fever. Seldom, if ever, has a case of the fouling of water intended for human consumption, so gross or so persistently maintained, come within the cognisance of the medical department, and seldom, if ever, has the proof of the relation of the use of water so befouled to wholesale occurrence of enteric fever been more obvious and patent." (Report of the medical officer of the Local Government Board for 1892-93.)

In 1891 Mr. E. L. Jacob traced an outbreak of 25 cases at Catteshall Paper Mills, near Godalming, to the temporary use of the water of the river Wey for drinking. "At one of the houses in the borough of Godalming which drained into the river Wey above the mills there were some cases of typhoid fever in April and May; the specific poison of the fever, therefore, was probably passing into the river from that house at the time when it was distributed to the cisterns in the clay-room at the mills." (*Public Health*, vol. iv., p. 188.)

An outbreak of typhoid fever at King's Lynn and Gaywood (Norfolk) was reported on in 1892 by Dr. Bruce Low. This outbreak was particularly interesting because it was ushered in by a "sudden outbreak of diarrhœa attacking all classes and all parts of the town during the last few days in February, followed by development of numerous typhoid cases about a fortnight later." This outbreak was due to the fact that the water-supply of the town was derived from Gaywood river which flows through cultivated fields and gardens. The intake of the water is within the borough boundary and the filtration adopted is very insufficient. The contents of privy pits in the town into which the discharges of some typhoid fever cases have been thrown were spread before the time of the outbreak on part of a market garden abutting on the river and about a mile above the intake of the water-supply and the "excreta from a house outside Gaywood wherein eight persons were attacked one after the other with typhoid fever between November and March had been placed in a pit in the garden, from which it was washed into the river above the intake by the melted snow and heavy rainfall that occurred in the third week in February."

Dr. Bruce Low reported in 1893 on an outbreak at the villages of Nunnington and Ness-in-Ryedale (Yorks). The water-supply of these villages is derived from the river Rye which is largely polluted by the sewage of Helmsley and by the washings from land on which local privy "muck" and Leeds town manure are spread from time to time. The chief interest in this outbreak is that it was cut short by all the water used for all domestic purposes being boiled. In 1895 Dr. Bruce Low reported on an outbreak of typhoid fever in September in certain riverside villages below Helmsley, just after the outbreak at that town caused by infected milk (see page 94). This outbreak was "confined to those persons who drank raw river water taken from the Rye at points below that at which it is polluted by the sewage of Helmsley."

Dr. Maclean Wilson reported in 1893 on a sudden outbreak of typhoid fever at Chester-le-Street (Durham) which was followed after a short interval by another equally sudden. The sufferers in both cases were almost entirely persons using one public water-supply which had before the commencement of both outbreaks been contaminated by enteric fever discharges from some cases in a group of cottages about three miles above the intake of the water company. The sewage from these cottages ran by means of a covered drain into a small stream, a tributary of the Stanley burn which supplies the filter-beds of the company, but these filter-beds were quite inefficient for the purpose of preventing any germs of enteric fever contained in that water from gaining access to the street mains of the company.

In 1897 Dr. F. St. G. Mivart reported on a sudden outbreak of typhoid fever at King's Lynn borough and Gaywood parish (Norfolk) early in October. The fever was distributed indifferently throughout both places. The water-supply was derived from the river Gaywood "which is exposed freely to pollution of all kinds throughout its course." The river water was delivered without filtration, an abundance of contaminating matters having been washed into the river by the excessive rainfall on Sept. 29th.

In 1899 Dr. S. W. Wheaton reported on an outbreak in the borough of Ilkeston (Derbyshire) as follows: "Fever prevalence in all probability due to pollution of the general water-supply of the town, which is derived from the Nut brook and imperfectly filtered. The water of the Nut brook is grossly polluted by liquid refuse from dwellings at Henor, effluent from the Henor sewage farm, and numerous other sources of contamination."

In the twenty-second annual report of the State Board of Massachussets for 1890 is a report on typhoid fever in its relation to water-supply by Mr. Hiram F. Mills, in which it is stated: "Twenty-five years ago the average number of deaths by typhoid fever in 10,000 inhabitants in the places which are now cities in this State was 7·8, the number now dying yearly from this disease in the same places is 4·6 in 10,000 inhabitants. In fact, the actual number of deaths from this disease 25 years ago in these places, when their population was only six-tenths as much as at present was as great as it is now, and if measures for its prevention had not been taken and the death-rate had continued as it was 25 years ago we should now have 1000 deaths yearly, when the actual number in the cities is about 600. By carefully plotting upon maps of the cities the residence of all cases reported to the local Board of Health, together with the deaths, the distribution, though not even over the whole city nor strictly proportioned to the density of population, was so general that it could not be attributed to possible cases of typhoid fever at two or three of the large number of farms that supplied milk to the 100 or 200 milkmen who distributed milk through the territory where the cases of disease were found. On the other hand, the cases found in Lawrence were all within the territory supplied with water from the city waterworks, and several of the cases were in the thinly settled and apparently very healthy portions of the city, near the outer limits of the water-pipes. In Lowell the cases were very generally distributed throughout the territory, the numbers following nearly the density of the population. These conditions and the discovery of a probable cause of the contamination of the Lowell water-supply by fæces of typhoid patients discharged into Stony Brook, only three miles up stream from the intake of the Lowell waterworks, followed in a few weeks by the very rapid increase in the number of deaths from typhoid fever in Lowell, and these deaths followed in about six weeks by an alarming increase in the number of deaths in Lawrence, whose water-supply is drawn from the Merrimack river nine miles down stream from where the Lowell sewage enters the river, and the further discovery in December of typhoid fever germs in water from the service-pipes of the city of Lawrence, induced the board to send to the Mayor of Lawrence" a letter "warning the citizens not to use the city water for drinking until after it has been boiled for at least 15 minutes; and that when boiled it should not be cooled by putting into it ice obtained from the river this winter. This precaution should be continued as long as typhoid fever prevails in Lowell."

And he sums up the results of his investigation as follows: "We have found this relation existing between typhoid fever and water-supply—viz., that in general in the cities of the State the death-rate by typhoid fever has been greatly reduced by the introduction of a pure public water-supply; that in the one city, where there has not been such a reduction, a portion of the people use for drinking water from canals or from wells subjected to serious pollution by sewage; and that the deaths from this disease are much more frequent among that portion of the community than among others. The only two remaining cities which have not decreased death-rates by typhoid fever after the introduction of public water-supplies receive their supplies from a river polluted by sewage; and the seasons in which this disease prevails in these cities are later than those of other cities, and in the lower city on the river later than in the upper city, at a season when other cities are nearly free from the disease and at the time when it would follow if produced by the sewage from the upper city; further, that when the water of the river which passed the upper city and received its sewage during the greatest prevalence of the disease there had reached the service-pipes of the lower city, and there was the greatest prevalence of the disease in the lower city, typhoid fever germs were found in water from these service-pipes."

In the twenty-fourth volume of the reports and papers of the American Public Health Association for 1898 an account is given by Dr. John Leal, health officer, Paterson, New Jersey, of an outbreak of which he says: "No possible common means of infection could be found except the public water-supply, upon which all of those affected, with the possible exception of two or three, were dependent for at least a portion of the 24 hours. It also appeared that the only section of the city which did not contain a single case of the disease was also the only section not furnished with the public water-supply." It appears that "a resident of Little Falls (a place on the river above Madison) returned from a summer resort ill with typhoid fever on August 28th. The fever subsided about Oct. 1st but a relapse followed, lasting from about Oct. 8th to the end of the month, when finally convalescence began. The water-closet receiving the discharges of the patient was connected with a series of cesspools, connected with each other by overflow-pipes, and the last cesspool of the series discharged through a hidden pipe into the river. These cesspools, having thus become infected about Sept. 1st, continued to receive fresh infection until about Nov. 1st, when the patient was actually convalescent." Bacteriological examination of the water above Little Falls gave a negative result both as to bacillus coli and bacillus typhosus, but "below Little Falls the chemical evidence of harmful pollution was found, the average number of bacilli per cubic centimetre was 600, and in 90 per cent. of the specimens examined colonies of the common colon bacillus appeared." On a specimen taken at the intake on Sept. 23rd Dr. Connolly reported as follows: "Tests for typhoid bacilli revealed the presence of a non-liquefying active-motile bacillus which did not produce gas in the presence of culture media containing sugar, nor did it produce indol, and in other respects was identical with the typical bacillus of typhoid fever." On Nov. 24th the discharge pipe from the last cesspool into the river "was discovered and further infection from that source prevented. Not more than 28 cases were infected after this date and of the 28 cases 18 were infected within the first week and seven within the second week after it. Thus it appears that within two weeks of the shutting off of fresh infection the typhoid bacilli already in the river had practically disappeared owing to surrounding conditions not being so favourable as in the cesspools and to the effect of the downward flow of the current. It seems reasonable to believe, however, that the infection of the river and its attendant results might have continued indefinitely, owing to the conditions favourable to bacterial life existing in the cesspools, had not those sources of infection been discovered and cut off."

In the twenty-fifth volume of the reports and papers of the American Public Health Association for 1899 Dr. Leal reported on an outbreak at Paterson which he showed was caused by the public water-supply derived from the river Passaic "which at least 98 per cent. of those infected were known to use for at least a portion of the 24 hours." In the course of his report he says: "The suspicion thus cast upon the public water-supply as being the only factor common to the case was confirmed by the following facts: First. The only section of the city in which the disease did not appear is the only section not having the public water-supply. Second. The city of Passaic, supplied from the same source, was found to be suffering from an outbreak of typhoid fever at the same time. Third. The course of the epidemic was marked by sudden rises and falls. Fourth. These rises and falls were preceded by heavy rains and, consequently, rising waters." He found that the outbreak was caused by the excreta from a case of typhoid fever which developed during the early part of August, 1898. "The drainage from the premises of said patient was through a pipe into a small tributary of the Passaic river about 8000 feet above the intake. The local board of health, learning of the case on August 23rd, at once cut off drainage from said tributary, so that infection directly from said case ceased on that date." The water from the tributary had to run through a swamp before joining the river and refuse from a glue and gelatin factory also contaminated the waters of the tributary.

The theory evolved by Dr. Leal from these facts is as follows: "That the said tributary was infected from said case of typhoid while high from the heavy rain of August 10th; that the infected water of tributary spread over said swamp and, falling, left numerous pools, puddles, &c., cut off from the natural channel. That in these pools, puddles, &c., existed the conditions favourable to the vitality and multiplication of the specific bacilli, these conditions being the low dilution, the unusual amount of organic matter on account of the glue and gelatin factory, the close and rank vegetation, &c. That a certain number of these bacilli were washed down the river by the rising water following each rain, with a certain amount of damage as a result—the greater the rainfall the greater the amount of damage done. That the infection of new cases ceased after the first week in February is explained by the fact that the general thaw following the heavy rain of Jan. 24th changed said swamp into a raging torrent, thoroughly washing it out and keeping its entire area under three to 10 feet of water for two or three weeks."

An interesting report by Dr. H. C. H. Herold, the president of the Board of Health, on an outbreak at Newark, New Jersey, is contained in the same volume. It appears that Newark was formerly supplied by the Passaic river, the water of which was contaminated, but that in April, 1892, that supply was abandoned and a supply known as the Pequannock water system was adopted. After this there was a steady decrease in the number of cases of typhoid fever until 1898 when there was a marked increase, especially in August and September. This was found to be due to "shortages" in the daily Pequannock supply having been met by turning in contaminated water from the Passaic river.

My friend Dr. Pistor of Berlin has kindly forwarded me a copy of a report by Dr. Räuber of Remscheid (Rhine Province) on a serious outbreak in that town in 1900. There had been a few cases yearly since 1890 and a small outbreak in 1899, but in 1900 the number of the cases rapidly increased until there were no less than 118 cases between July 9th and 21st. The cause was found to be from the water of one of the streams contributing to the water-supply having become polluted (*Zeitschrift für Medizinalbeamte*, Heft 19, 1901), and also one by Dr. Mewius of Cosel (Silesia) on an outbreak at Leukan and two other villages on the course of the same ditch which supplied them with water and which was contaminated by the excreta of two typhoid fever patients in a cottage higher up (*Zeitschrift für Medizinalbeamte*, Heft 17, 1900).

Whereas the seasonal prevalence of typhoid fever is normally in the autumn months this disease is more prevalent and fatal in London during the winter months. Since 1890 I have pointed this out for St. George's, Hanover-square, for which I was formerly medical officer of health, and the following table from my report for 1900 shows that during every year except 1897, the monthly average for November and December was higher than that for August, September, and October.

Cases of Typhoid Fever.

Year.	August, September, and October.		November and December.	
	Number of cases.	Average per month.	Number of cases.	Average per month.
1891	6	2·0	12	6·0
1892	15	5·0	15	7·5
1893	16	5·3	18	9·0
1894	14	4·6	29	14·5
1895	11	3·7	10	5·0
1896	15	5·0	15	7·5
1897	16	5·3	6	3·0
1898	7	2·3	18	9·0
1899	14	4·7	11	5·5
1900	13	4·3	10	5·0
Average	12·7	4·2	14·4	7·2

This rise in the number of cases of typhoid fever reported in the months of November and December "is coincident with the increase of organic matter in the drinking water due to the flooded state of the river." On account of my condemnation of the water supplied during the month of December, 1898, in my report for that month, in which I stated that the samples of water supplied by both the companies (Grand Junction and Chelsea) were, according to Mr. Cassal's analysis, of "decidedly inferior quality," both of the companies wrote letters on the subject, forwarding with them reports by Professor Sir Edward Frankland and by Sir William Crookes and Professor Dewar, on which I prepared the following report:—

"With regard to the letters from the water companies, on which you have asked me to report to you, I find that the reports sent with them confirm my opinion of the inferior quality of the samples of water supplied in December as deduced from the results of the analyses made by your public analyst, Mr. Cassal.

"Thus Professor Sir Edward Frankland, in his report, referring to the Thames companies, says, that 'owing to heavy floods and insufficient storage the water sent out by all the companies, except the West Middlesex, *contained an excess of organic matter* which was, however, *almost* entirely of vegetable origin' (the italics are mine). It is true that he says it 'was in every case efficiently filtered before delivery,' but this means that it contained no notable quantity of suspended matters and neither did Mr. Cassal's analyses show any excess of such matters.

"Sir William Crookes and Professor Dewar, in their report, make no remark on the amount of organic matter beyond stating that 'the purity of the water in respect to organic matter has been determined by the oxygen and combustion processes.' From the results of their analyses, as shown in their tables, I find that the 'oxygen required to oxidise the organic matter' averaged for the Grand Junction Company 0·071 of a grain per gallon, and for the Chelsea Company 0·063 of a grain per gallon, whereas in the month of September last it averaged only 0·025 for each company; in other words, the amount of 'oxygen required to oxidise the organic matter' was for the Grand Junction Company nearly three times as much, and for the Chelsea Company two-and-a-half times as much as that required in September.

"I may remind you that this impurity of the waters supplied during the winter months is no new thing. I have reported on it year after year since 1873, and you may remember that you have addressed complaints to, and received similar answers from, the water companies many times before.

"I may also remind you that I have pointed out that for several years (with the exception of 1897) there have been more cases of enteric (typhoid) fever in the parish per month during November and December than during the preceding three months, and also that this disease has been unusually prevalent and fatal in London during the last three months. Now November, December, and January are not the months for the 'seasonal prevalence' of this disease, and, therefore, some other cause for the excess of it must be sought for, and it may be something more than a coincidence that in those very months London is supplied with water which, according to Sir Edward Frankland's report, contains 'an excess of organic matter.'" (Feb. 14th, 1899.)

In answer to this the following letter signed by Sir William Crookes for himself and Professor Dewar was sent to the vestry clerk by the directors of the Grand Junction Water Company:—

"Our attention has been drawn to a special report on the water-supply by Professor W. H. Corfield, medical officer of health to the

Parish of St. George, Hanover-square, fr m which it appears he confirms the opinion of Mr. Cassal that the water delivered by the Grand Junction Company during December last was of inferior quality. This is diametrically opposed to the opinion we have arrived at from our extensive experience of the conditions of the water-supply from day to day.

"Dr. Corfield draws attention to the fact that both our report and that of Sir Edward Frankland on the character of the water-supply to the metropolis during December last show that the majority of the Thames-derived supplies contained an amount of organic matter in excess of the average amount. This observation is simply an expression of the fact that all river-derived supplies have a period of maximum and minimum amount of organic matter during the course of the year. The maximum generally occurs in Thames water during the winter months and the minimum during the summer; and, as Sir Edward Frankland stated in his report for December, the over-charge of organic matter was 'almost entirely of vegetable origin.'

"The same remark applies to the amount of oxygen required to oxidise the organic matter. It is nothing unusual for river supplies to require three times as much oxygen during some period of the winter as compared with the summer supply. With regard, then, to the Thames supply during the month of December last, there was nothing exceptional in the oxygen absorption.

"Dr. Corfield, having pointed out these admitted facts, nevertheless puts an erroneous construction on what Sir Edward Frankland and ourselves intend to convey by our statement that the water before delivery had been efficiently filtered. Dr. Corfield seems to think that this is intended to express that the supply contained 'no notable quantity of suspended matters,' whereas our intention, and no doubt that of Sir Edward Frankland, was to convey that the water had not only been freed from matter in suspension, but had been bacteriologically purified to the extênt of over 99 per cent. from its natural condition; thus removing the suspicion of the possibility of its conveying any water-borne disease.

"Dr. Corfield proceeds to point out that enteric fever has been more prevalent in the parish of St. George, Hanover-square, during November and December than during the three preceding months and that the same remark applies to London generally. From this occurrence, combined with the fact to which we have above referred, relating to the organic matter, he suggests that the coincidence may be attributed to the cyclical excess of organic matter which occurs during the winter months.

"All the facts are against any such hypothesis. Our recorded analyses of the Thames-derived waters since 1881, together with the Registrar-General's statistics of enteric fever, enable us to state that there is no causal relation between the two. Indeed, this must inevitably be the case, for it is common knowledge that if any such disease as enteric fever originates through a contaminated water-supply, it is not the *amount* of organic matter but its *nature* that is the dangerous factor and this must be the presence of the specific living germ characteristic of the disease.

"No one has alleged that Thames water which has undergone storage and filtration similar to that of the London supply contains any such pathogenic organisms. It is true that Dr. Corfield seems to entertain a different view of the origin of typhoid epidemics, for during the course of the Maidstone inquiry, when it was proved beyond all doubt that one of the sources of supply had been grossly contaminated with fæcal matter and had been distributed to Maidstone without proper and systematic, or indeed any, filtration, Dr. Corfield, while admitting there had been pollution, said 'it was some vegetable pollution that had got in.'

"There is no comparison between the conditions of the polluted spring water-supply which originated the Maidstone epidemic and any polluting conditions which can arise in the Thames valley, where strict supervision of all sources of contamination is so efficiently maintained—a supervision which we know has materially improved the condition of the raw river water over what it was 10 years ago.

"We say deliberately that after mature investigation we know of no example of a water-borne disease having originated from a river supply where proper precautions are taken for adequate storage and effective filtration, such as exist in the case of the London water-supply." (31st March, 1899.)

This was referred to me by the committee of works, and I prepared the following answer to it, which was issued as a "Further Special Report on the Water-supply" :—

"In accordance with your instructions I have considered the report forwarded to you by the Grand Junction Waterworks Company, and signed by Sir William Crookes on behalf of himself and Professor Dewar, the company's analysts, and beg to report thereon as follows :—

"The report in question admits the fact that there is an excess of organic matter in the filtered river water supplied to London in winter, and explains it by the statement 'that all river-derived supplies have a period of minimum and maximum amount of organic matter during the course of the year. The maximum generally occurs in Thames water during the winter months and the minimum during the summer.' This is another way of stating what I have pointed out for many years past, that the water supplied by the Thames water companies during the winter frequently, and indeed usually, contains an excess of organic matter, due to the fact that the river water in winter is dirty from the washing of polluting matter from various sources into the river. To say that there is nothing exceptional in the occurrence of an excess of organic matter in the water in winter is merely to admit that the water in winter is generally polluted.

"The report next accuses me of putting an erroneous construction on what Sir Edward Frankland and the writers intend to convey by the statement that the water before delivery had been 'efficiently filtered,' in saying that this was intended to express that it contained 'no notable quantity of suspended matters,' whereas their intention 'was to convey that the water had not only been freed from the matter in suspension, but had been bacteriologically purified to the extent of over 99 per cent. from its natural condition.' This would seem to imply that bacteria are not suspended in the water, but as that cannot be intended I need only reply that I included them among the suspended matters, that my statement was strictly correct, and that apparently efficient filtration is not to be considered to include the removal of foul organic matter in solution in the water.

"The non-removal of such organic matter is, then, admitted by the company's analysts, and I may remind you that Sir Edward Frankland in his report for December, referring to the Thames companies, says that 'owing to heavy floods and insufficient storage the water sent out by all the companies, except the West Middlesex, contained an excess of organic matter which was, however, almost entirely of vegetable origin,' but the writers of the report in question go on to traverse my very temperate statement that 'it may be something more than a coincidence' that the exceptional prevalence of enteric fever in London during November, December, and January, which are not the months for the seasonal prevalence of this disease, occurs in the very months in which London is supplied with water which contains 'an excess of organic matter.' They say 'it is common knowledge that if any such disease as enteric fever originates through a contaminated water-supply it is not the *amount* of organic matter but its *nature* that is the dangerous factor, and this must be the presence of the specific living germ characteristic of the disease. No one has alleged that Thames water which has undergone storage and filtration similar to that of the London supply contains any such pathogenic organisms.'

"In answer to this I may, in the first place, point out that Sir Edward Frankland and others have over and over again found organisms in the filtered Thames water supplied to London, considerably in excess of the number taken as the standard—viz., 100 microbes per cubic centimetre.

"In a report recently issued by the Joint Public Health and Water Committees of the London County Council, I find that 'in the years 1896 and 1897 Sir Edward Frankland made 199 examinations of filtered water for the purpose of ascertaining the number of bacteria, and found that they varied from 16,000 per cubic centimetre down to nothing. The average, taking the whole of the 199 examinations, gave 232 per cubic centimetre, the standard admitted by Sir E. Frankland being that they should not exceed 100 per cubic centimetre. Out of the 199 days' examination by Sir E. Frankland there were 55 days in which the bacteria exceeded the standard, and for the whole 55 days they averaged 763 microbes per cubic centimetre; so that 28 per cent. of the results of Sir Edward Frankland's examination tend to show that the filters are not an effectual barrier against the passage of bacteria.'

"In the twenty-sixth annual report of the Local Government Board Sir E. Frankland states that 'in June, 1896, nearly the whole of the filter beds of all the companies became infected with bacteria.' Further on the same report states that 'the engineer of the Southwark and Vauxhall Water Company in the evidence recently given by him before the Royal Commission on London Water Supply admitted that in December, 1896, 16,000 bacteria per cubic centimetre were found in water that had passed one of their company's filters and that nothing was discovered to explain the fact.

"Drs. Parkes and Rideal have recently submitted a valuable joint report to the Chelsea Vestry on their examination of the water supplied by the Chelsea Waterworks Company from November, 1897, to November, 1898. In this report they clearly show that organisms of various kinds and in varying numbers passed through the filter-beds, some of these organisms being of the kind of which the bacillus coli communis, which is found in enormous numbers in sewage, is a type; and being found in 19 per cent. of the total number of specimens tested for them. Of this test they remark: 'The test, also, when it gives an affirmative result, not only tends to indicate the tainted sources of supply of the Thames, but also tends to show that the methods of sand filtration pursued by the company are ineffectual in eliminating from the filtered water microbes of which the common resting place is sewage and animal excrement.' The conclusions they arrived at are 'that even in a year exceptionally favourable to the purifying operations undertaken by the water companies, the element of danger necessarily attaching to the supply of a water taken from sources inevitably exposed to contamination is not by any means invariably eliminated by the methods of purification at present relied upon. A system of filtration which does not invariably keep out or destroy the common accompaniments of sewage and animal pollutions may, on the occasion of epidemic prevalences in communities on the river banks above the companies' intakes, also allow the passage of the infective disease organisms in numbers sufficient, as the case may be, to cause epidemics amongst the water consumers, or mere sporadic outbreaks, *or isolated occurrences amongst the more susceptible of the population.* We are, therefore, of opinion that considerations of public safety require that reliance should not be placed upon sand filtration as at present conducted, as the sole means of defence, when the water to be operated upon is derived from a tainted source. The question of the presence of "blood-heat" organisms in the water, their relations to season and to water temperature, and to the occurrence of diarrhœal complaints in the late summer, to which some reference has been made above, appear to be deserving of more prolonged and detailed investigation.' (The italics are mine.)

"As to the fact that 'pathogenic organisms' have not been found in the water supplied by the Thames companies I need merely say that the bacillus of enteric fever has rarely, if ever, been found in any water-supply. It was not found, for instance, in any sample of water supplied to Maidstone, and on this point Dr. Washbourn said in his report that '*no importance can be attached to the failure to discover the typhoid bacillus in water suspected of being the cause of an epidemic of typhoid fever.*' If this is so, it is still less likely that the typhoid bacillus would be found in water which is merely suspected of producing typhoid fever in those persons of the community who are peculiarly susceptible to it. In fact, the test which shows whether a water contains typhoid poison is not the discovery in it of the bacillus of the disease, but the fact of its producing or not producing that fever among the people who drink it.

"Sir Wm. Crookes and Professor Dewar allude to the Maidstone inquiry and say that 'it was proved beyond all doubt that one of the sources of supply had been *grossly contaminated with fæcal matter.'* The Local Government Board inspectors who conducted the inquiry came to no such conclusion; they merely say that the water sources 'were all exposed *to the risk of* pollution' and they add 'there is *no conclusive evidence* to show either how the specific pollution of typhoid fever was introduced into the supply, or which of the springs was thus polluted.' (The italics are mine.)

"As to the chemical evidence of pollution of the Maidstone water I have before me the table of analyses of the water referred to, and find that out of 22 samples examined five showed signs of organic contamination. In one sample this contamination was rather greater than in the samples of water supplied to St. George's, Hanover-square, last December, but not greater than in samples that have been supplied on other occasions, but in the other four it was less, and in all of them the results of analysis tend to show that the organic matter was 'chiefly of vegetable origin '

"The organisms found by Drs. Sims Woodhead and Washbourn in the Maidstone water were of similar kinds to those found by Drs. Parkes and Rideal in the waters supplied to Chelsea, and, as already stated, the typhoid organism was not found in any sample.

"The company's analysts go on to say 'there is no comparison between the conditions of the polluted spring water-supply which originated the Maidstone epidemic and any polluting conditions which can arise in the Thames Valley, where strict supervision of all sources of contamination is so efficiently maintained,' a conclusion diametrically opposite to that arrived at by the Public Health and Water Committees of the London County Council, who say in their report: 'We consider that in respect of physical conditions the causes which led to the typhoid epidemic in Maidstone have a parallel in the conditions of the London water-supply. The epidemic was caused by water drawn from polluted sources. It is admitted, and the facts above quoted conclusively show, that the water supplied to London is also derived from sources liable to become polluted. As Sir Alexander Binnie points out: 'This is but another instance among many which teaches the general lesson that for many years a population may be supplied with water from various sources without any apparent harm to the consumers and that the water so taken has been repeatedly pronounced after chemical examination to be pure and wholesome, but that if the water is derived from a source liable to pollution sooner or later the time generally arrives when an epidemic breaks out owing to circumstances connected with the pollution of the supply.'

"In this connexion the following remarks of Dr. Clowes, the council's chemist, are worthy of attention: 'While there are grounds for believing that the comparative immunity from typhoid fever which is enjoyed by the consumers of London water depends largely on the effective working of the filters, it must be understood that a breakdown in the filtering arrangements might possibly, at any time, produce a serious epidemic. And although the ordinary process may remove 90 per cent. of the bacteria which are at present in the river water, it is reasonable to suppose that the remaining 10 per cent. of the bacteria may occasionally number in their midst the bacillus of typhoid fever.'

"As Sir William Crookes and Professor Dewar refer to their 'extensive experience,' I may be permitted to remind you that I have reported on the water supplied to St. George's, Hanover-square, for the last 25 years, and with regard to their remark that I seem to entertain a different view of the origin of typhoid epidemics from that generally held, I may mention that I have seen some hundreds of cases of typhoid fever and investigated some thousands in this and other countries during the past 30 years; that 25 years ago I combated the then prevailing opinion, advanced by Dr. Murchison, that the poison of the disease was produced by the decomposition of fæcal matter, that, in fact, it originated *de novo;* and that I have for a long time past come to the conclusion, which many others share with me, that typhoid fever spreads in other ways than by the pollution of drinking-water.

"I am, nevertheless, of opinion that such other ways are not competent to account for the increase of typhoid fever in London during the winter months, when it ought to diminish, and that there is in all probability some connexion between this increase and the fact that the greater part of London is then supplied with water which contains 'an excess of organic matter.'

"I will also add that it is at any rate a remarkable coincidence that I am able this month to report to you that the number of cases of typhoid fever in London has very considerably diminished and the death-rate from it gone down to its normal amount now that the water-supply has ceased to show the signs of contamination to which I have drawn attention." (April 11th, 1899.)

To this no further answer was received from the advisers of the water companies.

Mr. Shirley Murphy, in his annual report for 1894 as medical officer of health of the London County Council, drew attention to the fact that the distribution of cases of typhoid fever in London "was characterised by the increase of prevalence in the forty-ninth, fiftieth, and fifty-first weeks," and that this late outbreak was exceptional and "was observable in the population supplied by all the London water companies except the East London and the Kent Companies. Also that the water supplied from the Thames and Lea was polluted owing to the fact that severe floods had occurred in November." He also states that: "Inquiry as to the behaviour of enteric fever in populations in the vicinity of the county gives indication of some difference of behaviour of this disease in the population supplied by water from the Thames and Lea and in the population otherwise supplied, the population supplied from these rivers experiencing an increase of disease in the forty-ninth, fiftieth, and fifty-first week, corresponding with that experienced in London. The hypothesis of water-borne contagion appears better able than any other to afford explanation of the increase of disease in the weeks in question."

I have no doubt from the above facts that the unseasonable prevalence of typhoid fever in November and December in London is due to the distribution of inefficiently filtered river water containing the poison of the disease, in sufficient amount, however, only to attack the most susceptible persons among the population.

Dr. S. Davies, the medical officer of health of Plumstead, reported in 1893 that the cases of enteric fever among the men employed in the Arsenal were caused by their habit of drinking water used for an engine and drawn from the Arsenal canal. This water is liable to be polluted with the excreta of labourers and is very liable to contain the infection of enteric fever. This reminds me of the account given by Dr. de Renzy of the prevalence of typhoid fever at Millbank Prison when it was supplied with water drawn direct from the Thames. On supplying the prison by means of an artesian well the disease became as rare there as it was frequent before.

There are very few instances in which sewage irrigation on land has been shown to be the cause of typhoid fever. It is indeed a remarkable fact that typhoid fever does not occur among the employés on sewage farms, even when they drink the water of wells on the farm, which is frequently the case. In some few instances, however, owing to mismanagement of some kind or other, outbreaks of typhoid fever have occurred in connexion with sewage irrigation. One was the outbreak at Beverley in 1884 already referred to.

In not a few instances—and some of them very important ones—the water-supply has become polluted while in the mains, whether on constant or intermittent service, by the specific poison of typhoid fever and serious outbreaks have been caused by this. Thus Dr. Alfred Carpenter communicated a paper to "Public Health" in July, 1873, entitled "The Danger of an Intermittent Water Supply when delivered by house services designed for use under constant pressure."

He had noticed that cases of sickness, diarrhœa and typhoid fever broke out in houses in Croydon after the constant water service had been temporarily replaced by an intermittent service, and that the tap-water was complained of as not being good; he found that water from the soil was sucked into the water-mains through defective joints, and also that foul matters were sucked into them *through direct connexions with the basins of water-closets.*

At Lewes (Sussex) Dr. Thorne reported in 1874 that there was a "large epidemic of enteric fever due in the first instance to pollution of the town water-supply from water drawn from the Ouse, which receives the town sewage, and mainly spread by suction of polluting matter into the water-pipes of an intermittent water service" (Report of the medical officer of the Privy Council and Local Government Board, New Series, No. IV., for 1874). He also reported as follows on an outbreak at Wolverton: "Water-supply exposed to risk of pollution by suction of foreign matters from closet-pans into mains of an intermittent service" (Report of the medical officer of the Privy Council and Local Government Board, New Series, No. VII., for 1875). And on another at Tideswell, Derbyshire: "Spread of disease favoured by conditions in an intermitting water surface allowing of suction of foul air into water-pipes" (Sixth Report of the medical officer of the Local Government Board for 1876). Dr. Thorne also reported on an outbreak in the Dewsbury registration district as follows: "Water-supply for some districts liable to pollution at its sources and periodically fouled in delivery mains during intermissions in the service." And again in the Dewsbury Urban Sanitary District: "Water-supply subject to pollution at, and probably on its course from, the gathering ground. Supply intermittent and liable to be fouled by suction of filth into mains (Eighth Report of the medical officer of the Local Government Board for 1878).

In 1874 Dr. F. R. Blaxall reported on an outbreak at Sherborne (Dorset) as follows: "The influence of milk in the distribution could be excluded, but respecting the circumstances of the water-supply the following facts were ascertained. During December, 1872, and January, 1873, the water was frequently shut off from the town at a point near to the reservoir and the same thing was done every night in February. It is known that when the water was shut off there were certain delivery pipes up which there was a rush of air immediately the tap was unscrewed. Now many of the openings to the pipes are situated in the pans of the water-closets. At night, after the closet had been used, the tap would be turned on for the admission of water; none flowing, the tap, in many instances, would not be turned off again; thus, a direct passage into the water mains would be left open, but the accidental circumstance of leaving the tap open was not required as many taps were broken and admitted a continuous flow of water during the day but at night, no water being present, were uninterruptedly open to sewer air. Through these openings during the night air commonly passed from the closet-pan to the water-pipe; in other words, the system of pipes for the water-supply became the means of ventilating the closet-pans; if a trap happened to be broken or out of order it became a means of ventilating the sewers, and if a pan happened to be full of excrement, that excrement would be sucked into the water-pipe. In January and February, when there were at least 27 cases of enteric fever in the town, closet-pans thus circumstanced were doubtless in some instances tainted with the specific contagium of enteric fever; some may even have been filled with excrement from the bowels of fever patients. The sewer air which entered the pipes at night, when the water was turned off, would in the morning, when the water was turned on again, be driven forward, washing the pipe surfaces on which foul air had for hours been resting, and could hardly (even supposing no actual excrement to have got into the pipes) have failed to contain fever contagium; and this water went on, not only to cleanse closet-pans, but to be drunk by the people in the town. I think it probable that the recent outbreak of enteric fever was caused by persons drinking of this contaminated water and I base this opinion on the following considerations: first, the sudden appearance of so many cases in the first week in March—i.e., after the water had been shut off every night in February; secondly, by the gradual diminution of cases after the first week in March, during which month the water was not turned off at nights; thirdly, by the manner in which the cases were scattered about the town; lastly and mainly, by the fact that the proportion of cases occurring amongst persons who derived their water from the board of health supply was much greater than amongst persons who had their water from other sources" (Report of the medical officer of the Privy Council and the Local Government Board, New Series, No. II., for 1873). In 1882 the same inspector reported on another outbreak of typhoid fever at Sherborne produced in exactly the same way.

In the same volume is a remarkable report by Dr. Buchanan on an outbreak which occurred in 1873 at Caius College, Cambridge, from which I extract the following: "All the more usual ways of enteric fever spread have now been considered and none of them have appeared adequate to account for the intensity of incidence of fever upon Caius College or for its remarkable incidence on Tree Court. Holding always in view the special character of these occurrences let us observe that the *water-supply* to the college is taken from a surrounding five-inch main at six different places, and that one of them, at the Gate of Humility, is for Tree Court and for no part but Tree Court. What if there should be something wrong with this one local supply? Even *primâ facie* there is something to be said for this view. The suddenness of the outbreak in the college was such as at once to suggest to Dr. Paget and Dr. Bradbury, and equally to myself, the thought 'that it might be due to the contamination of the water or milk.' The area of the particular water distribution is exactly the area of the fever, at least of 12 out of 15 cases, one or more of the remaining cases requiring probably no explanation beyond every-day circumstances. The good character of the company's general water-supply would not avail as an argument against a local contamination in a local service. And at an early period of my investigation I was struck with the circumstance that while every water-closet in the old part of the building was provided with a cistern proper to itself, the closets in the Tree Court buildings were supplied with water direct from the high-pressure constant-service pipes. Complete intermission of supply was found to have actually occurred on two occasions at least during the last term. The earlier occasion can be defined as the evening of the second day of an October frost, and thus far might have been either on Oct. 25th or on Oct. 30th, but other associations suggest Oct. 25th as being the more probable of the two days; on this occasion only the particular service through the Gate of Humility was stopped. The latter occasion was when the water company's servants, having, for the purposes of pipe repair, cut off the water-supply of some half of Cambridge, there was hurrying to restore the supply in order to gain water-power to blow the organ of King's College Chapel for a musical service. This fixes the date of the second known intermission at about 10.30 A.M. on All Saints' day, Nov. 1st. Now a fortnight is about the incubation time of enteric fever. A fortnight after Oct. 25th is the date of the first attack in Tree Court. A fortnight after Nov. 1st is the date of the second, third, and fourth attacks. And though it was known that other cases of fever kept dropping in till the end of November the coincidence of the early fever with these ascertained intermissions was not the less suggestive as indicating the direction that further inquiry should take." Dr. Buchanan then showed that the water in that main was contaminated by suction into it, during the periods of intermission of the supply, of foul air from a soil-pipe (and so from a sewer) through a "weeping pipe" which supplied the trap on the waste-pipe of the safe-tray of a water-closet, which trap was liable to siphonage. (Report of the medical officer of the Privy Council and the Local Government Board, New Series, No. II., for 1873.)

In the annual report of the medical officer of the Local Government Board for 1887 is an important report on an epidemic of typhoid fever in the Mountain Ash Urban Sanitary District, Glamorganshire, by Mr. John Spear, in which, after discussing the evidence, Mr. Spear continues: "The facts all tend to bring into more and more prominent relief the point of *initial* contamination of the water, and, in view of the now clearly established premises of my argument, the exact condition of the Oxford-street main and its relation to immediate surroundings become matters of exceeding interest and importance. I have shown that the water, as it passed into the main and for the first 160 yards of its course there, produced no ill-effects in its consumers; and I have identified that point just at the Henry-street bifurcation as the one point indicated by the facts of fever prevalence where specific contamination of the water main had in all likelihood habitually occurred. For the purpose of this inquiry the two pipes were laid bare a little above and for some distance below the point indicated. The Henry-street pipe was laid some 25 years ago and has been found to be much corroded. That of Oxford-street was relaid, as I have said, in 1885. *There is no doubt that the relaying was very carelessly, not to say recklessly, done.* Owing to the exigencies of water-supply it was done mostly at night, and the work being in private hands was subject to no supervision on the part of any official or authority having concern with the public health. Accordingly, the main was carried, without any special precaution, *immediately above, alongside, and even through the old rubble drains:* and when in the course of trenching pipe-drains were cut through no trouble appears to have been taken to replace them. I find the inspector of nuisances reporting in September, 1885, a third case of injury and stoppage of a drain from this cause. Although the old stone culverts to which I have referred are not ostensibly sewage-carriers now they formed the sole sewage system some 20 years ago; and even now refuse matters are often poured, as I saw myself, into the roadside gullies that are connected with them. One of the culverts through which the Oxford-street main was carried (a 'collar' or junction between two pipes being in the interior, was found to contain a quantity of excessively foul sewage deposit, a slaughter-house apparently, amongst other places, draining into it. It may be said that, as one result of the careless laying of the main, the latter was at different points from time to time bathed in refuse matters and habitually at certain points in sewage-contaminated air."

Leakages were found in the mains and also direct connexions with the water-closet pans. "Of course, during intermission of water pressure, the flaws in the pipes represented by the 'leaks' would afford means for the entrance into the pipes of air from the soil, or from the neighbouring drains as the case might be, and doubtless of liquid also. I had myself opportunities of observing how considerable was the suction of air into the pipes at certain points after intermission of supply and on its renewal how much air coming with much noise and force had to be expelled. No special valves being provided for the purpose this air must have entered by accidental openings. At any time of intermission it is plain that the leaky water-pipes were at liberty to discharge their contents through any opening at a lower level and that they would convey not only such water as remained in them but those matters also which entered at the points of leakage. In short, the leaky pipes would act as so many means of draining the ground in which they were placed. Passing through or alongside old rubble culverts they would take up foul air and liquid from these culverts and from the soil around and would deliver these matters at lower levels (if not during intermission, on the first renewal of supply) for consumption as 'drinking-water.' Intermission of water-current, however, is not by any means essential to the introduction of foreign matters into water-pipes. Under various physical conditions very powerful insuction of external matters into a full-flowing water-pipe can take place. Some of these conditions were considered in a departmental report on Croydon in 1875. It results from the foregoing observations that during intermissions of the service large contamination of the water of the Oxford-street and Henry-street mains must have occurred and that contamination, although on a comparatively minute scale, during continuance of supply is probable. Chemical analysis of the water, and still more microscopical examination, afford important confirmatory results. Dr. Dupré, to whom samples were sent for analysis, reports that water taken from a house tap in Henry-street *before the nightly intermission of service* was pure, while that from the same tap after intermission gives evidence of animal contamination and of the appearance of low forms of life. Water from a tap in Victoria-street (Miskin) shows similar deterioration both in the night and morning supplies."

An interesting case at Buckingham in 1888 was reported upon by Dr. Franklin Parsons. There was a sudden outbreak of typhoid fever in that town in January and February, 1888, confined at first to a poor suburb of the town, and especially affecting persons drinking water from a particular "spout." "The water conduit to this spout was exposed to pollution from a leaky drain which had received specifically infected excreta from a previous case of enteric fever."

An outbreak of typhoid fever at Fareham (Hants) was reported by Mr. Spear in 1888 to have been traced by the medical officer of health "to pollution of an intermittent water-supply through numerous direct connexions between the water mains and the pans of water-closets. After this was remedied and a constant supply of water afforded enteric fever became less prevalent in the town." Mr. Spear also reported in the same year that an outbreak had taken place in Flint, where the water-supply was intermittent and where in the specially infected locality there was an "allegation of discolouration of the water when turned on in the morning." In 1889 Mr. Spear reported that at Strood and Rochester, where typhoid fever had been prevalent, he "found water-closets supplied direct from the mains—i.e., without the intervention of any cistern or tank. The danger of insuction of air and even of solid matter into the water-pipes from closet-pans during any temporary disconnexion of water-pressure is well known to attend this objectionable arrangement."

Dr. Wheaton reported in 1893 on an outbreak which was almost entirely confined to a limited area in the town of Atherstone (Warwick). The "outbreak was not due to excrement disposal, sewerage, drainage, or milk-supply; *but to the introduction nightly into the town water mains for a period of eight weeks of an extraneous water-supply which was subject to pollution.* The localisation of the fever outbreak was explained by the peculiar distribution of the water mains owing to which the suspected water was almost entirely consumed within the area to which the fever in question was almost entirely confined. The prevalence of the disease was in part due to infection from the privy-middens, also to contamination of water-supply by a residue of suspected water remaining in the mains and continued consumption of the same water, which was obtained from a public tap."

In 1899 Dr. G. S. Buchanan reported with regard to a serious outbreak at Falmouth (Cornwall) that there were "reasons for inferring that insuction of infectious matter into Falmouth water mains during periods of intermission of supply had concern with the epidemic." The water-pipe, in which there was a roughly made and leaky joint, was laid underneath the stones of a yard where the soil was "everywhere black and impregnated with foul organic matter." This was caused by the leaky drain and a water-closet down which typhoid excreta had been thrown, and Dr. Buchanan proved by a test that suction into this main actually did take place under certain circumstances.

Drinking water may also, *after it has been delivered into the house*, be contaminated with the poison of typhoid fever. In illustration of this point I may be allowed to quote again from my paper "On the alleged spontaneous production of the poison of enteric fever," read before the Epidemiological Society of London in March, 1874. "In large towns the enteric fever poison spreads chiefly through the medium of sewer air, in which it is doubtless suspended, and in London I find that this fever especially prevails in houses where the waste-pipe of the drinking-water cistern communicates directly with the house-drain, a sanitary defect which is very common indeed in many parts of London, especially in old houses in the best neighbourhoods; to quote from my report on the sanitary condition of the Parish of St. George, Hanover-square, for the year 1873:—'Out of 39 houses in which there were cases of enteric fever, 22 had the sanitary defect in question; while there were 11 other houses with the same defect, in which cases of low fever, or some other ill-defined disease, were found. It may be mentioned that diarrhœa frequently breaks out in such houses.' The waste-pipe being a ventilator, and often the only one to the drain, the foul air, which may contain, suspended in it, some of the poison of the disease, rises up this pipe into the space between the water in the cistern and the cover, and the suspended particles fall into the water which is drunk, and which may, and often does, give rise to enteric fever in the persons drinking it." There can be no doubt that the remarkable diminution in the number of cases of typhoid fever in London during recent years is very largely, if not chiefly, due to the disconnection of the waste-pipes of drinking-water cisterns from the drains.

We now come to the distribution of the disease by means of *infected milk*. In 1862 an investigation was made by Professor John Gamgee on Cattle Disease in Relation to the Supply of Meat and Milk, and his report was published in the fifth report of the medical officer of the Privy Council. He came to the conclusion "that the cause at present operating most actively to deteriorate the milk of cows in this country is the prevalence of epizoötic aphtha. This disease attacks the human subject and many cases of communication from cattle to man have been observed either from the virus penetrating a wound or passing into the system with the milk." Sir John Simon adds to this: "Experiment seems to have established as certain that, at least under some circumstances, the human affection may be caused by the consumption of milk drawn from a diseased animal." And it is stated in a footnote that "more than 20 years ago Professor Hertwig published particulars of such experiments performed by him on himself and two friends with the result of producing a very definite eruptive fever."

Dr. Edward Ballard, when medical officer of health of Islington, first traced an outbreak of typhoid fever to a particular milk-supply in 1870. This investigation is so important that I insert the following lengthy quotations from his report: "The general result of an inquiry into the milk-supply of the families within the quarter-mile radius into which I ascertained that typhoid fever had entered was this—viz.: That it occurred in the house of the milk vendor where the business, was carried on. He died and seven other persons, members of his family or boys employed and living on the premises, had typhoid fever and one of the latter died. That it occurred in the family of a person who dwelt in a small cottage in the cowyard distant about 100 yards from the last-mentioned house and dairy, three persons having fever here. The first case here was in a girl, who, a fortnight before she actually fell ill, had left a situation at a public-house supplied with milk from this dairy and since then had been residing at home. This family, the mother of the girl told me, rarely took milk, except on Sundays, being poor, but when the girl was ill milk was given to them from the dairy. The mother herself, and subsequently a little boy, had typhoid fever when the girl was convalescent. That, in addition to the two boys who had lived in the house for a longer or shorter time, two men engaged in the business who did not live in the house had typhoid fever. One of these was the cowman engaged after the master was taken ill; the other was a young man who worked at the cowyard and carried out milk and who took all his meals at a coffee-shop supplied from the dairy and where two families also supplied from the dairy had fever. That a fifth man employed at the cowyard and residing at home had fever. He also occasionally had his meals at the above-mentioned coffee-shop and his tea at his mother's who was supplied from the dairy. His family being poor he bought no milk for them anywhere and he was the only member of it attacked. That another single man residing within the radius in a wholesome house and engaged as a coachman outside the radius, who habitually took his meals at this same coffee-house, had an attack of typhoid fever. That (omitting the girl who came ill from the country) out of 62 other families within the district which are known to have suffered from typhoid fever, 54, or fully 87 per cent., were constantly supplied from the dairy with the milk they required, two were occasional customers, and five only stated that they did not deal there at all. I am not quite sure that complete reliance can be placed on this last statement; certainly I doubt it in one case of the five. All five resided close to the dairy and it is very probable obtained there, as the most convenient place, any extra milk their families required. In another instance a girl was attacked in a family not supplied by the dairy, but it appeared that on two consecutive days in the beginning of July she had taken tea with a school-fellow who, with her mother, had typhoid fever a few days later, this family being supplied from the dairy. No one else in this girl's family had fever."

On inquiring into the fatal cases happening in families residing in the quarter-mile radius from the dairy he found, "That the members of 142 families were supplied with milk from the dairy in question. The district within the quarter-mile radius alone must contain over 2000 families. So, after all, no very considerable proportion got their supply from this source. Out of these 142 families (which include the dairyman's household) I have ascertained that 70 were invaded by typhoid fever within the 10 weeks during which the outbreak extended—that is to say, half of them were invaded. This includes all the families which had deaths from typhoid fever." On searching for the cause of the contamination Dr. Ballard found that it came from an underground wooden tank constructed 16 years before which had become rotten and was found to communicate with two old drains by means of rat-burrows in such a manner that not only foul air from the drains but also an overflow of sewage itself could obtain access to the tank. The water from this tank was used for washing the milk-cans.

An outbreak at Balsall and Moseley Heath, near Birmingham, was investigated in 1873 by Dr. Ballard who thus sums up its etiology:—"1. Two wells upon adjoining premises occupied by milk-sellers became infected early in November with the infectious matter or virus of enteric fever through the soakage from a privy into them of excremental matters containing that matter of infection. 2. Through the medium of water drawn from these wells the milk supplied by these milk-sellers became infected and many of their regular customers who drank the milk suffered from the disease. 3. The same infected milk having been sold to two other milk purveyors, some of the persons using the milk supplied by these milkmen also suffered in a similar manner. 4. There is no evidence that the disease spread in these districts in any other way than through the consumption of these infected milks" (Report of the medical officers of the Privy Council and the Local Government Board, New Series, 1874).

A serious outbreak of typhoid fever in Marylebone was investigated in 1873 by Mr. J. Netten Radcliffe and Mr. W. H. Power, the former making the country inspections and the latter the inquiries in London. Mr. Radcliffe was also accompanied in his inspections by Dr. Whitmore, the medical officer of health of Marylebone, Colonel W. Hope, V.C., and Mr. Chalmers Morton, representing the company supplying the milk, and myself as medical officer of health of St. George's, Hanover-square, and also for that occasion sanitary adviser to the company. "Early in the outbreak Dr. Murchison, whose family suffered very severely from it, satisfied himself that the only probable mode of introduction of the disease into his house was by the milk-supply. The suspicion having been aroused, he quickly ascertained that almost the whole of the families which were then affected with enteric fever within his knowledge and that of his professional friends, obtained their milk from the same dairy which supplied his household. The preliminary inquiry had made it certain that the milk of six out of the seven farms supplying the dairy was, at the time of the outbreak, free from any suspicion of infection with enteric fever material. But with regard to the milk from the seventh farm the result was very different. Here a condition of things was found which rendered it highly probable that milk from this farm had been charged with enteric fever material and not improbably with the excremental discharges of a patient suffering from enteric fever, shortly before and during the earlier period of the outbreak in Marylebone. *From this farm was obtained all the milk specially supplied by the implicated dairy for nursery use, the consumption of which milk, as has already been shown, furnishes the strongest evidence of the infection of the milk.* On June 8th the occupier of the farm died suddenly in the fourth week of an attack of ambulant enteric fever (typhus ambulatorius). For some time previous to the seizure it had been suspected that he suffered from some disease of the heart. The suddenness of the death at a time when it was believed by his medical attendant that recovery from the enteric fever had commenced led to the death being ascribed to the presumed heart disease and to its having been certified as occasioned by this cause, no mention being made in the certificate of the disease from which he was considered to be recovering at the time of death. The history of this case, indeed, is that of well-marked ambulant enteric fever. Previously to the hæmorrhage there had been no disturbed action of the bowels. After the hæmorrhage Mr. Humphreys (the medical attendant) gave directions that all discharges from the bowels and bladder should be kept out of the common privy of the farmhouse and buried somewhere outside the premises. This direction was carefully carried out, and from the first hæmorrhagic stool to the last chamber slops all the discharges were removed to an ash-heap beyond the precincts of the farm buildings (as will presently be more fully described) and there the evacuations from the bowels were buried and the slops cast. No disinfectant was mixed with either the one or the other before being got rid of; for, on the one hand, it did not seem to be necessary from the place of burial or casting away, and, on the other, it was not advisable to retain upon the premises the great bulk of the evacuations passed within a brief period until a disinfectant had been procured. On August 12th, a son of the above patient, aged 13 years, was seized with enteric fever, and he passed through a slight but well-marked attack.

"A series of carefully executed excavations were carried out under the supervision of Colonel Hope, V.C., one of ourselves and the manager of the implicated dairy being also present, to determine whether soakage from the privy and from the drains of the farmhouse could find its way into the dairy well. A previous examination of the interior of the well, the water having been pumped out for the purpose as low as practicable, disclosed a well-marked line of soakage through the interstices of the brick steining on the south side of the well, three feet six inches above the inlet of the drain from the feeding well and nine feet from the surface. Other more doubtful points of soakage existed, which need not be described. These excavations proved conclusively (1) that no soakage was possible from the privy into the dairy well; (2) that no soakage had taken place either from the surface yard drain or from the dairy drain into the well; and (3) that no soakage from the farmyard drain or the farmyard or elsewhere had passed along the upper part of the trench in which the conduit from the well in the meadow to the dairy well was laid. These questions having been carefully put aside a trench was run up to the yard wall from the garden plot on the south side, a little to the east of the position of the well, and on digging beneath the foundation of this wall unquestionable signs of soakage of some foul matter were found. On this being discovered an excavation was made between the well and the yard wall and a line of soakage disclosed along the foundation of the wall through the made earth intervening between the wall and the well to the point where soakage had been discovered in the well. The reason of the growing foulness of the water from this well, which had caused its disuse some time before for drinking and cooking, now became at once obvious. The soakage could only come from one direction—that of the pigsty. The yard wall and the southern wall of the pigsty were continuous. The drainage of the pigsty flowed to the south side of the wall and there accumulated. The surface drainage from the yard was also occasionally dammed up against the wall, as one of us at the time of the first inspection of the premises had occasion to see. Now there can be no reasonable doubt, from the result of the excavations, that the drainage of the pigsties and of the yard had in the progress of time made its way along the foundation of the wall, a distance of about 25 feet, to the vicinity of the well and then soaked through the intervening soil into the well. The latter process from the nature of the soil would be a slow one, but it had been accomplished so effectually that the clay which constituted the bulk of the made ground between the wall and the well was, along the line of soakage, reduced to the consistence of very soft paste. Against the wall along the foundation of which this soakage takes place and close to the pool formed by the drainage from the pigsty is the ash-heap of the farm. In this ash-heap were buried all the evacuations from the bowels of the sick occupier of the farm on June 1st, 2nd, and 3rd, and upon it were cast all the chamber slops of the sick man's room from June 1st to 8th. *In other words, by an unhappy and altogether unforeseen chance and in carrying out precautions to obviate any possibility of mischief the matters from which mischief was most apt to arise were deposited in perhaps the only spot on the farm premises where they would certainly find their way into the water used for dairy purposes.*

"For the ultimate purpose of this inquiry it is sufficient to have shown a probability, amounting for practical purposes to a certainty, that (1) the outbreak of enteric fever which forms the subject of inquiry was caused by milk infected with enteric fever material; (2) that this milk came from a particular farm; and (3) that the water used for dairy purposes on this farm contained excremental matters from a patient suffering from enteric fever immediately before and at the time of the outbreak" (Report of the medical officer of the Privy Council and the Local Government Board, New Series, No. II., 1874).

In the seventh annual report of the medical officer of the Local Government Board, 1877, is a report on an unusual prevalence of enteric fever at Ascot during a period of four years and a half by Dr. E. Ballard, from which I quote the following: "In the middle of 1873, at the very time that the outbreak in Marylebone which was traced to the milk-supply of a particular dairy was in progress, three cases of enteric fever occurred almost simultaneously on the top of the ridge of hill on which the village of Ascot stands. ......

"The three cases occurred in persons who had recently been in London, *and two of whom had certainly when there used the milk of the particular dairy.* I failed to get evidence of the third case having partaken of that milk." Dr. Ballard makes the following interesting observation :—

"*What is to be gathered from coincidences?*—In an inquiry into an epidemic such as this, where the cases of the disease are distributed about a district having certain common features, there are four sources which are ordinarily looked to as those whence the contagium of the disease is most likely to have proceeded and by the medium of which it may have been distributed, viz.: (1) a common source of water-supply, such as some particular well or stream or the mains of a system of public supply, in which case infection of the water, either at its source or in its progress for distribution, may result in the distribution with it of an infective material; (2) a common system of drainage, in which case a sewer becoming infected may be the means of distributing, through the medium of the sewer air, infective matter to the houses in relation with such sewer; (3) where there is no common water-supply and no common system of drainage to account for a wide distribution of fever, the cause of the spread may be found in the progressive infection of independent privies, &c., and by soakage from them into independent wells or other supplies of drinking-water; or (4) the cause of the spread may be found in the distribution over the district of some particular article of food, such as milk, which has become infected."

Dr. Ballard then shows that the first three sources were not operating in this case, but that the fourth was, almost all the families infected being supplied with milk from a farm known as the Brick-kiln farm, and he comes to the following conclusion: "The facts which I have detailed can leave, I think, no doubt upon the mind that the use of milk distributed from Brick-kiln farm was in some way directly associated. as cause with effect, with the distribution of enteric fever through the Ascot and Sunninghill districts during the long period of four and a half years.* It is no valid objection to this inference to say that many families to which this milk was distributed have hitherto escaped invasion, and that a few families which used milk from other sources suffered similarly from fever. The obvious reply to the first of these objections is that in no milk epidemic hitherto investigated has more than a fraction (although usually a large fraction) of the families using the infected milk been invaded; and to the second objection that the operation of one predominating cause of an epidemic of fever by no means precludes the operation of other causes concurrently existent." After describing the premises he adds: "The above account of the condition in which I found the farm and dairy premises, and of the slovenly arrangements under which the business was conducted, indicates more than one way in which the milk might have become befouled. It is obvious that the cans in which the milk was sent out were liable every day or any day to befoulment even during the process of cleansing. The water used for rinsing the cans was a dangerous water to use for the reasons just assigned, being doubly liable to befoulment—namely, first, from the soakage of foul matters into the well from privies and the manure heap, and, secondly, from the absorption of the foul emanations from the drains which communicated with the pump case. After rinsing they were again liable to befoulment from drain emanations rising through the sink pipe over which they were sometimes inverted to drain. And, finally, the milk itself might at any time have become befouled by standing in the room into which the sink pipe opened. In addition to all which the brush used in cleansing the cans and the rags used for the same purpose, or for plugging the pump spouts, might, from their constant vicinity to the sink pipe, have become fouled by the drain emanations and thus have become a medium by which these filthy emanations might have been conveyed to cans. With respect to the open cistern within the pump case I may point out that its circumstances were similar in all essential points to those of the water cisterns in many London houses, where the waste-pipe opening above into the space between the water and the cistern cover is continued without any break or intervening trap into the house-drain, and is liable to carry up sewer-air into that interval, whence it may be absorbed by the water. There is abundant evidence to show that enteric fever has, in London, been frequently caused by the use of cistern water stored under such conditions. I have specially mentioned the circumstances under which the water used may have introduced a filth pollution into the milk by merely rinsing the cans with it, because former experience of milk epidemics of fever have demonstrated that given an infected water the small quantity of such water which may hang about a milk-can after rinsing with it is amply sufficient to infect the milk subsequently put in. The infection of milk by an infected water by no means implies fraudulent dilution of the milk with that water, of which, moreover, there is no evidence in this instance. To all this I may add that there is an accidental way in which filth may gain access to milk, which must never be overlooked,—namely, from the hands of the milker." He then asks: "*Had the 'filth' that had access to the milk any opportunity of receiving specific infection?*—This is a further question some attempt to answer which will be expected by those who subscribe to the doctrine that (putting mere possibilities aside as not matters of scientific argument) enteric fever contagium as we now meet with it has an ancestry; and however long and widely and through whatever media it may have travelled about prior to finding a lodgment suitable for its development in a human system, that it or its ancestor at one time issued with excremental matter from some individual affected with the disease. It is a doctrine which I myself provisionally accept as most in accord with my own experience and also, so far as I have been able to judge, with that of the most competent and, let me add, most patient observers. With such as dissent from it I can agree in admitting that there is very much in the natural history of contagium in general, and of enteric fever contagium in particular, wrapt in an obscurity yet unpenetrated; but I am hopeful enough to look forward to the time when the advance of scientific inquiry will render that clear which is now dark."

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* "The low fatality which has attended the epidemic corresponds also with experience as to other epidemics of enteric fever due to milk, only two persons out of the 69 died."

Lastly, he made investigations on this important point and came to the conclusion "that there were various opportunities for the 'filth' thus introduced into the milk to become specifically infected with the infective matter of enteric fever." It is interesting to note that in the specification of works to be done at this dairy a brick dipstone trap (now quite obsolete) is specified and a sketch of it is given.

An outbreak at St. Albans in 1884 was investigated first by Dr. C. E. Saunders, the medical officer of health, and afterwards by Mr. Shirley Murphy for the Local Government Board. This was a simultaneous outbreak of typhoid fever in St. Albans and in London among the consumers of milk coming from a farm near the former city. Although the disease was undoubtedly traced to the milk, which must have been contaminated, there was an absence of evidence that the milk at the farm had become infected in any of the commonly believed ways, but there was "some reason for believing that the milk from this farm, which had in the summer of 1883 given rise to a serious outbreak of enteric fever in St. Pancras, had retained, although to a slight degree, power of infecting its customers in the interval between the two outbreaks." The great interest and importance of this conclusion are obvious.

Dr. Airy reported in 1885 that there was a severe outbreak of typhoid fever at Lower Sherringham (Norfolk) under circumstances pointing to contamination of milk-supply, but that the origin of the infection was uncertain.

Mr. Harvey reported in 1886 that epidemic typhoid fever at Swanage (Dorset) was "associated at its commencement with the use of milk from a dairy situated on the polluted brook and without water-supply on the premises."

In 1886 Dr. J. Ashburton Thompson, then an inspector under the Board of Health of New South Wales, presented a report on an outbreak of typhoid fever in the municipal district of Leichhardt, which he had traced to polluted milk and in which he draws the following conclusion as to the cause of the outbreak: "All possible causes have now in turn been examined. It has been shown that its attack and decline were alike sudden; that it occurred at a time when the district affected by it was practically free from fever; and that it was almost entirely confined to customers of a particular dairy, cases of fever among others than customers being very few, and two having had ample opportunity at least of sharing the milk. It has been shown further that these customers lived under general conditions which were equally shared by all the inhabitants of the district, their number being 615 and against very nearly 10,000 who were not customers. It has been shown, therefore, that the condition common to the persons attacked must have been one to which the persons who escaped were not subject; and that the only condition answering to this requirement is the consumption of milk supplied from the Helsarmel dairy to the former." At the dairy the well water was shown to be practically sewage and it was highly offensive at the time of calling—in fact, the sewage of a number of houses and the drainage water of a cemetery soaked into it, and Dr. Ashburton Thompson was able, moreover, to show that it was specifically infected from the excreta of a recent case of typhoid fever in the neighbourhood.

In 1887 Dr. B. A. Whitelegge, then medical officer of health for Nottingham, reported on a small outbreak of typhoid fever which he had traced to a particular milk supply. The interest of the case consists in the fact that the customers were partly supplied by milk from the dairyman's own cows, which was taken round *by cart*, and partly by milk obtained from three other milk dealers in the town, which was served directly *by can* from the dairy. "It became evident from the preliminary enquiries that a disproportionate number of the attacks were among those households supplied by cart. Of the 31 cases it finally appeared that 19 were in households supplied exclusively by cart, and only 3 in those supplied exclusively by can. Suspicion was thus directed to the dairyman's own supply, and was confirmed by finding an almost complete absence of cases of enteric fever in households supplied by the three dealers from whom the milk was obtained. Some of the six farms sending milk to these dealers also supplied other dairies in the town, but without any occurrence of enteric fever among their customers." On further investigation Dr. Whitelegge "came to the conclusion that the milk was probably infected by some person employed in its distribution," most likely a helper who came from the Union at the date of the probable beginning of the milk infection.

Dr. Page reported in 1888 that an outbreak of typhoid fever at Spennymoor (Durham) was associated in time with prevalence of fever at a farmhouse whence milk was distributed to a considerable number of the persons attacked. Dr. Bruce Low reported on an outbreak at Shildon and East Thickley (Durham) in 1893. There were scattered imported cases during May, June, and July, followed by a considerable outburst of the disease in August and September, the number of cases gradually diminishing in October and November. "The earlier cases were mild, anomalous, and irregular, the later cases typical and severe. Many cases admittedly escaped disinfection and established foci of infection." A large share in the diffusion of the disease was attributed to a particular milk service. "In the milk-seller's house there occurred three or four unnotified cases believed to have been enteric fever. The dairy where the milk was stored communicated directly with the sewer, without a bend or trap, by means of a four-inch pipe in the sink stone. History of flooding of milkman's cellar by sewage on two occasions in July after heavy rainfall. The public water-supply had nothing to do with the outbreak."

In 1895 Dr. Bruce Low reported on a sudden outburst of typhoid fever in August in the town of Helmsley, North Riding (Staffs.), confined to the customers of a particular milk-seller, a member of whose family recovering from this fever came on a visit to his house from July 11th to August 24th. The outbreak suddenly terminated in September on the stoppage of the sale of the polluted milk.

At the International Medical Congress of 1881 Mr. Ernest Hart read a paper on the Influence of Milk in Spreading Zymotic Disease in which he placed on record 73 outbreaks of disease as having been traced to the agency of milk, and of these no less than 50 were outbreaks of typhoid fever; and in 1897 he published another report on the same subject in the *British Medical Journal*, giving short accounts of 95 more outbreaks (occurring between 1882 and 1896), of which 48 were those of typhoid fever, making together 98 outbreaks of typhoid fever traced to the agency of milk by the end of the year 1896.

Dr. D. S. Davies, medical officer of health of the city of Bristol, read an important paper before the Epidemiological Society in March, 1898, "On an Outbreak of Milk-borne Enteric Fever in Clifton." In this outbreak the cases varied from the mildest, which would not otherwise have been recognised as typhoid fever cases at all, to the severest type of the disease, mild and severe cases being found in the same houses. The outbreak, as is so often the case with those due to milk, showed an excess of attacks among children under 15 years of age. There were 244 cases in all, of which 230 "were shown to have obtained either regular or occasional supplies from one or other of the three infected rounds." Of the remaining 14 cases four were accounted for in other ways. The connexion of the fever with certain milk-supplies may be considered to have been established without a doubt.

In 1899 Dr. W. W. E. Fletcher reported on an outbreak at Coleford (Gloucestershire), which place was almost free from typhoid fever from 1895 to 1898, when an outbreak occurred which he found to have been "intimately connected with one particular milk-supply."

In May, 1900, Dr. Fletcher reported to the Local Government Board on an outbreak of typhoid fever in the Urban District of Coleford and in the Rural District of West Dean (Gloucestershire). Dr. P. Buchanan, the local medical officer of health, had already ascertained that "although the drainage and sewerage of the towns are highly unsatisfactory and the polluted state of the water-courses dangerous to health, the outbreak was caused by contaminated milk; there was some difficulty in ascertaining how the milk had become contaminated. It appears most probable to have been either by washing the milk cans with polluted water from a well or by the fact that one of the workers in the dairy suffered from a mild attack of typhoid fever and that the milk he distributed somehow became infected from him."

In the twenty-sixth report of the State Board of Health of Massachusetts for 1894 Dr. William T. Sedgwick reports on an outbreak at Marlborough as follows: "While a very brief investigation had established the fact that the epidemic could not possibly be attributed to the public system of water-supply or sewerage the true source of the outbreak still remained to be found and I next turned to the milk-supply as a possible vehicle of the disease. But it soon became plain that many different milkmen were involved and that therefore ordinary milk could not have been the common carrier of the infection. Closer inquiry, however, finally disclosed the fact that very nearly in the middle of the infected district was a 'creamery' which, although private, served in a manner as a milk-centre for the whole city. This creamery bought milk from 28 different farms which constituted its regular supply. It also bought from time to time from the various independent milk-pedlers whatever milk they had left over and wished to sell after their daily rounds. On the other hand, the creamery sold to the various milk-pedlers whenever their own supplies 'ran short' and in these ways served, as it were, as a kind of 'clearing-house' for the milk-supply of Marlborough. My suspicions at once rested, largely because of its central location among the cases, on the creamery and very soon after upon this special skimmed-milk service. I therefore made in the next place a house-to-house investigation which established beyond all possible doubt the fact that there was a common bond existing between most of the cases. It had not escaped observation that the disease was confined to those of slender means or in poor circumstances, and closer investigation showed that some who had attempted to economise in their milk-supply by using skimmed milk had suffered most severely." He ultimately satisfied himself that this skimmed milk was the cause of the epidemic and concludes his report with the following observations: "As far as I know the present is the first case on record in America in which an epidemic of typhoid fever has been apparently due to the use of infected skimmed milk; but it is easy to believe that many obscure outbreaks of this disease may have come from a similar source. With the multiplication of creameries to which milk (or cream) is brought from numerous and various farms the possibility must be kept in mind of contamination of the whole product by one infected contributory portion; and inasmuch as skimmed or 'separated' milk, on account of its cheapness and freshness, is now much used not only for cooking but also for drinking, this product, as well as the 'whole' milk, must henceforth be regarded as a possible vehicle of infectious disease."

Dr. Pistor of Berlin has kindly forwarded me copies of papers from which I extract the following:—

I. Dr. Ricken of Malmedy (Rhine Province), writing on Typhoid Fever and Dairies, cites several instances of outbreaks traced to polluted milk; thus at a place called Reuland a general distributing dairy for skim-milk was established in 1897, and an outbreak soon occurred producing 73 cases in 36 houses, with 10 deaths; of these 22 houses were supplied by the dairy; moreover, all the families of the employés of the dairy, except one, suffered from the disease and in each village where an employé lived it was in that family that the disease first broke out. At Büllingen a dairy was opened in April, 1899, and an outbreak soon occurred and was traced to the dairy having been supplied from four houses where there had been cases of typhoid fever shortly before. The results are stated as follows:—(*a*) Of 316 houses of customers of the dairy 48 were attacked, or 15·2 per cent. (*b*) Of 210 houses not served by the dairy 20 were attacked, or 9·5 per cent., while in one of the villages (Wirtzfeld) of 34 houses of customers of the dairy 10 were attacked, or 29·5 per cent., and of 50 houses not served by the dairy eight were attacked, or 16 per cent. Moreover, of the 116 cases in this village no less than 35 were children under 15 years of age. At Nidrum, in the district of Malmedy, an outbreak among the soldiers of the camp of Eisenborn which recently took place was traced to the use of infected milk, supposed to have been sterilised but evidently not efficiently so. The way in which the milk became infected was not traced but typhoid has been endemic in the district for some years. At Auro (district of Prüm in the Eiffel) in 1898 a widespread outbreak was attributed to skim-milk distributed from the dairy there, because all the cases occurred in houses supplied by that dairy. In 1899 another outbreak occurred at Bleialf in the district of Prüm and was traced to another dairy (Zeitschrift für Medizinalbeamte, Heft ii., 1901).

II. Dr. Schlegtendal of Aix-la-Chapelle has collected accounts of outbreaks traced to polluted milk-supplies in Strasburg, the Canton Lucerne, Connecticut, Montclair New Jersey, Lübeck, Aix-la-Chapelle, Hamburg, and a number of other places; the one at Aix was particularly interesting as it was brought about by cases in the house of a dairyman, which were called by the medical attendant "gastric fever" and were not notified to the public authority and therefore no precautions were ordered; the excremental matters of the patients were thrown on a dung-heap from which they soon soaked into the well, the water of which was used to wash the milk-cans. The outbreak ceased on disuse of the well-water and connexion of the dairy with the town water-supply. The circumstances of this outbreak were very similar to those of the Marylebone outbreak in 1873. (Deutsche Vierteljahrschrift für Offentliche Gesundheitspflege, vol. xxxii.).

III. Dr. J. Adolf Kraemer gives a very interesting account of an outbreak in an infantry regiment. Tired out by a long march in July and very thirsty the soldiers came to a place where they were given plenty of milk. The result was that 142 of them fell ill about the end of the second or beginning of the third week after drinking the milk; of these "81 had true typhus abdominalis, 31 febris typhosa sive gastrica, and 30 had indefinable symptoms." It appeared that in the house whence the milk was obtained there was a person suffering from typhoid fever and this case was at first regarded as the source of the outbreak, but it was found afterwards that it was contracted at about the same time as the cases among the soldiers and the poison appears to have been derived from a case which occurred in the previous year (Zeitschrift für Klinische Medicine).

LECTURE III.

Delivered on Feb. 27th, 1902.

MR. PRESIDENT AND GENTLEMEN,—Other foods have been proved to become occasionally the vehicles for the poison of typhoid fever.

In 1881, at the meeting of the British Medical Association at Cambridge, Sir Charles A. Cameron read a paper entitled "Sewage in Oysters," in which he pointed out that sewage which might perhaps contain the microbe of typhoid fever was sometimes present in oysters, and he had often found it in oysters taken from the shores of Dublin Bay.

On March 29th, 1894, Dr. Newsholme, the medical officer of health of Brighton, reported to the Sanitary Committee of that town "particulars of 8 cases of enteric fever which had occurred during the preceding quarter, and which were attributable to *the consumption of oysters* derived from oyster layings grossly contaminated by sewage."

And on April 19th in the same year he brought before the Committee particulars of further cases arising from the same cause. "At the same time samples of mud from the market ponds in question were submitted to bacteriological examination by Dr. Boyce (now Professor of Pathology, University College, Liverpool), who stated that the results pointed 'unmistakably to the presence in the immediate vicinity of the oyster beds of sewage matter contaminated with human excrement.'

"On December 7th in the same year a deputation from the Brighton Town Council waited upon Sir Walter Foster, then Parliamentary Secretary of the Local Government Board, and brought the matter to his notice."

On December 11th, 1894, in the Seventeenth Annual Report of the State Board of Health of the State of Connecticut, U.S.A., Professor H. W. Conn reported on an outbreak of typhoid fever at the Wesleyan University there. After excluding the drinking water, the ice used in ice-water, the milk, the ice-creams, the meat, and the groceries, it was found that oysters obtained from the dealers at Middletown were the cause of the disease. These oysters were served at certain suppers at which were a number of persons who were not students of the college, among whom cases of typhoid fever also appeared at the same time as those in the college. For instance, of five Yale students who attended the banquet two developed typhoid fever. It was found that those only suffered who had eaten the oysters raw. One of the "fraternities" which had eaten the same oysters but had them cooked did not suffer from the disease. On examining the source of the oysters it was found "that at the rising tide an eddy was found to be setting along the shore from the region of the sewer outlet up stream in the direction of the oyster beds. This condition would plainly make it possible for typhoid contaminations from the sewer to be carried to the oysters." It was also found that two cases of typhoid fever occurred in a house discharging into the sewer in question at about the time that would be necessary to bring the possibility of infection to the date when the oysters sent to Middletown were collected. Experiments were made by Mr. Charles J. Foote of the Yale Medical School which showed "that the typhoid organism will live in the oysters long enough to have the oysters taken to Middletown and be eaten. In these experiments the bacilli typhi abdominalis were forced in between the shells of the oysters from the creek and were found alive and capable of growth at the end of 48 hours. This is all that is required to account for the outbreak at Middletown."

Professor Conn says: "If one had planned beforehand a series of experiments designed to prove the possibility of oysters as distributing typhoid it would hardly have been possible to have devised a more satisfactory series of conditions than those which had attained in this outbreak." The following is his own summary of "the chain of evidence which leads to the conviction of the oysters as the cause of the Wesleyan epidemic." "1. The dates of the cases appearing at Wesleyan, all between Oct. 20th and Nov. 9th, plainly point to a single source of infection to which all the afflicted students were exposed at about the same time. This must have occurred a little more than a week earlier than the appearance of the first case, and the initiation suppers perfectly fill the conditions. 2. That these initiation suppers were the source of infection is rendered certain from the fact that four of the visitors who attended these banquets and have had no further connexion with the fraternities have developed typhoid simultaneously with the cases in college, and by the further fact that two visiting Yale students who attended the suppers have similarly suffered from typhoid. 3. The fact that only three out of seven fraternities holding suppers on that evening suffered from typhoid pointed to some article of food or drink used at these three suppers and not used in the other fraternities. 4. The fact that about 25 per cent. of the students attending the suppers have suffered from typhoid pointed to a universal and very active source of infection and not to an incidental one. Whatever article of food contained the infectious material must have been eaten by nearly everyone present to account for such a large percentage of cases. 5. Only one article of food or drink was used by the three societies which was not used equally by the other four fraternities. This article of food was oysters and they were eaten raw. 6. These oysters came from a creek, where they had been allowed to fatten for a day or more, within 300 feet of the outlet of a private sewer and in such a position as to make contamination from the sewer a possibility. At the time that the oysters were there deposited there were two persons in the house supplying the sewer who were in the incubation period of typhoid fever, the period during which no attention would be paid to their excreta. 7. Typhoid germs are not injured by sea-water or oyster juices, and if they found their way into the oyster would certainly have lived long enough to be sent to Middletown and be served on the tables of the fraternities. 8. Twenty-three cases of typhoid fever followed among the students in attendance on the suppers at which the oysters were eaten, and six cases among persons in attendance and not among the present students at Wesleyan. In all of the cases of undoubted typhoid it has been possible to trace either direct or indirect connexion with these oysters. The oysters were also eaten raw by one family in town and at least one severe case of typhoid followed. 9. The use of oysters from the same locality by the students at Amherst College produced, or all events was followed by, an outbreak of typhoid fever among the students who ate of them. These facts taken together form a chain of evidence practically complete at every point and leaving no room for doubt. Whatever may be said in regard to oysters in general the Wesleyan outbreak of typhoid was caused by a special lot of contaminated oysters." (Supplement in continuation of the twenty-fourth annual report of the medical officer of the Local Government Board, 1894–95.)

In "A Note on the Transmission of the Infection of Typhoid Fever by Oysters" Sir William H. Broadbent described several cases of typhoid fever occurring in houses with excellent sanitary arrangements, but traceable to oysters eaten from 10 to 14 days before the attacks. He also mentioned cases of city men who had eaten oysters at lunch suffering while their families were not attacked, and he declared that "the evidence of communication of typhoid by this means has been of such a character as to produce a conviction in my mind" (*British Medical Journal*, Jan. 12th, 1895).

In a supplement in continuation of the report of the medical officer of the Local Government Board for 1894–95 is a very important report by Dr. H. T. Bulstrode on Oyster Culture in Relation to Disease. In this report accounts are given with diagrams of the layings, fattening beds, and storage ponds in various counties round the coast of England and Wales, from which it appears that those belonging to the larger and more important oyster companies are "in the main free from the risk of dangerous sewage pollution ; and that, moreover, where security in this sense does not obtain it may, ... in not a few instances at least,

—— be easily brought about by the simple expedient of altering the position of the fattening beds or storage pits." But, on the other hand, he showed "that there are cases where the risk of sewage pollution to oysters is so great and indefinable that nothing short of complete diversion of the sewers or drains or withdrawal of existing fattening pits or ponds from use can be regarded as satisfactory in the public interest."

In his subsequent annual reports Dr. Newsholme showed "that 38·2 per cent. (1894), 33·9 per cent. (1895), 31·8 per cent. (1896), and 30·7 per cent. (1897) of the total cases of enteric fever originated in Brighton were caused by sewage contaminated shell-fish."

This induced the Brighton sanitary authority to attempt, in 1896, "to obtain Parliamentary powers authorising them to prohibit the sale within the borough of shell-fish known or suspected to be the cause of infectious disease," and in 1897 a memorial was presented to the Local Government Board that such powers might be conferred upon local authorities generally.

A Bill to this effect was brought before Parliament in 1899, but was withdrawn.

In 1896 Dr. R. Bruce Low reported on an epidemic at Southend, Essex, in which he found that there was "some evidence of certain cases having been due to eating oysters which had been spread on 'layings,' or kept in boxes, along the foreshore, where they were liable to be contaminated with filth from the pier water-closets and by sewage from the sewer outfall." (Twenty-sixth report of the medical officer of the Local Government Board.)

In June, 1896, Dr. Chantemesse read a paper before the Académie de Médecine of Paris on Oysters and Typhoid Fever. In this paper he described an outbreak in the little town of Saint-André-de-Sangoins, in the Mediterranean department of Hérault, which was caused by a barrel of oysters from Cette, which were eaten raw by 40 persons, all of whom became ill, while in the six houses where the oysters were eaten those members of the family and domestics who had not eaten any were not attacked. Of the 40 persons attacked eight suffered slightly from abdominal pains, vomiting, diarrhœa, and general malaise; four others, the youngest, who had not eaten many, suffered severely from abdominal gurgling and pain with general malaise and great prostration. Two others, aged 20 and 21 years respectively, suffered severely from attacks of typhoid fever and one of them died. It was found that at Cette, where were the layings from which the oysters were brought, there was plenty of opportunity for them to be contaminated by sewage. Dr. Chantemesse collected from one of the chief merchants in Paris fresh oysters from different places as soon as they arrived in Paris and found that many of them contained the bacillus coli. He placed some of these, while living, in sea water intentionally mixed with typhoid excreta.

After leaving them for 24 hours in this water he removed them and kept them for another 24 hours to represent the time they would take in being delivered to the consumers. After this time they were still living without any particular smell and were of good appearance. Nevertheless, bacteriological examination showed that they contained in their bodies and in the water round them not only the bacillus coli but the living typhoid bacillus.

In 1897 Dr. G. S. Buchanan reported on recent cases of typhoid fever at Brightlingsea and several urban and rural sanitary districts in Essex and Suffolk. There were 26 cases of which he says: "Each of these cases undoubtedly enteric fever, each ascertained to have been that of a person who had partaken of oysters at a date antecedent to illness consistent with occasion of oyster eating having been occasion of infection ; in which no conditions, irrespective of oysters, to which infection could be attributed." He found that the oysters came from "layings" on a foreshore in Brightlingsea Creek conspicuously exposed to pollution by the sewage of Brightlingsea which is discharged untreated into the creek. He further ascertained that "at sundry different periods during 1897 infectious matters from enteric fever cases in Brightlingsea must needs have been discharged from Brightlingsea sewer outfalls."

I find from Mr. Shirley Murphy's annual report for 1897, as medical officer of health to the London County Council, that the following cases in various London districts were referred in that year to the eating of oysters *or other shell-fish*. The medical officer of health of Paddington reported that of the 45 cases (of typhoid fever) recorded during the year three appeared to have been due to the patients nursing other cases and two to eating oysters (origin unknown). In two cases there were histories of consumption of ice-cream and mussels, but the information was too unreliable to be accepted without reservation. At Fulham in the same year three cases were thought to have been due to the consumption of shell-fish. In Marylebone one case "pointed specifically to the consumption of contaminated oysters." In Stoke Newington five cases "were ascribed by the sufferers to the eating of oysters." In the Strand at least six of the 18 cases appeared to have arisen out of eating uncooked shell-fish, five of them at a seaside resort. At Holborn three out of the seven cases, which were contracted outside of the district, were probably due to the eating of oysters. There were two similar cases in Newington, one in St. Olave's, and three in Wandsworth. In one case at Plumstead "the patient had eaten whelks eight days before his attack." In 1898 one case in Westminster was attributed to oysters. In the Strand "in two instances the disease is believed to have been acquired through eating shell-fish." In Wandsworth in three cases the disease was believed to have been contracted through eating oysters. In his report for 1899 Mr. Murphy gives the following summary under this heading: "In several reports it is stated that shell-fish had been eaten shortly before the beginning of illness; thus in one instance, in Paddington, cockles had been previously eaten at Southend. In Kensington, 'in several of the cases locally recorded, the sufferers had partaken of oysters, mussels, &c., at seaside resorts, within such periods of time antecedent to date of illness as to suggest a relationship of cause and effect.' In Fulham 'in five cases the origin of the disease was ascribed to shell-fish.' In Marylebone 'in several cases there appeared to be good evidence that the infection was taken in with such foods as oysters, mussels, or other shell-fish.' In Stoke Newington 'two cases doubtless contracted the disease outside London; the disease appeared to be due to the consumption of cockles in one case and to the consumption of oysters in another case.' In Holborn 'in three cases there was good evidence that shell-fish might have caused the disease.' In Newington 'in quite one-half of the cases notified within this period (middle of September to middle of November) the friends of the patients attributed the disease to the eating of shell-fish, presumably mussels. Certainly the eating of the mussels had taken place about eight or 10 days before the illness commenced or within the usual incubation period. The mussels were the Dutch variety.' In Lambeth in six cases there appears to have been a causal relationship between the attacks and the previous ingestion (within the incubation period) of infected shell-fish, in three cases oysters, in two cases mussels, and in one case cockles being the suspected medium. In Wandsworth parish in five cases 'the patients had partaken of shell-fish shortly before.' In Greenwich 'it was found that a great number of cases had partaken of various sorts of shell-fish, such as oysters, mussels, and cockles.' In Plumstead 'in two cases eating insufficiently-cooked mussels may have been the cause and in one case oysters.'"

The following cases were described in THE LANCET of March 3rd, 1900, p. 638: "Two servants, a footman and a maid-servant, employed at a country seat in Cornwall, were attacked by enteric fever soon after consuming certain oysters and the maid-servant succumbed to the malady. At the same house was a shooting party and two of the guests left on Nov. 11th after having during their stay eaten freely of oysters. These gentlemen were taken ill with enteric fever at their respective homes, the one on Nov. 24th and the other on Nov. 26th. Moreover, a lady guest left this house on Nov. 28th for Ireland, taking with her a supply of oysters, some of which she gave to her brother on her arrival. On Dec. 17th this brother developed enteric fever. All the oysters here in question were procured from the same source. ...... The suspected oysters were laid down in the Penryn river off the village of Flushing and opposite to the town of Falmouth"; into this river much sewage is discharged and Dr. Bulstrode considers the oyster-layings in it "as occupying a dangerous position."

In a preliminary report on "Cockles as Agents of Infectious Disease" Dr. Klein detected the bacillus coli in three out of eight cockles which had been taken from a foreshore polluted with the discharge from a sewer outfall and also the typical virulent bacillus enteritidis sporogenes in four of them, and in eight out of a dozen raw cockles in their shells bought from a street hawker "(1) no typical bacillus was found; (2) bacillus coli (typical) was found in five out of eight cockles; (3) virulent bacillus enteritidis sporogenes was found in four out of the eight cockles" (Report of the medical officer to the Local Government Board, 1899–1900).

In their report on enteric fever in Chichester in 1899 Dr. Theodore Thomson and Colonel Marsh say: "During May and June, when the fever prevalence was at its height in Chichester, there was considerable suspicion locally that the consumption of cockles, infected with the specific contagium of enteric fever, was responsible for the occurrence of no small number of cases of the disease. As result of careful inquiry it appeared probable that certain persons had actually contracted the fever in this way. Investigations on this subject were made locally in late July and early August, by which time nearly 70 cases of enteric fever had been reported to the local authority. As regards these cases it appeared that in 20 instances cockles had been partaken of within a month of the onset of illness; the remainder of the persons attacked by the fever had not partaken of cockles within that period. Of the 20 referred to 18 had eaten of cockles within three weeks of attack. In some instances, however, this relation in time between consumption of cockles and occurrence of the fever constituted the only apparent ground for attributing the latter to the former, but as regards 13 of these 20 persons probability of causal connexion was indicated by other evidence, such as nearly simultaneous onset of symptoms of the fever in two or more persons who had partaken together of cockles some 10 or 14 days previously, or the occurrence within 24 hours of consumption of cockles by several persons of sickness followed a week or two later by development of enteric fever in one or more of the consumers. In most instances it proved impossible to ascertain whence these cockles had been derived; but, as noted in the body of the report, many cockles known to be obtained from mud-flats liable to pollution by sewage are sold in Chichester. The share of the fever, however, which can reasonably be referred to consumption of cockles is but small. The 13 cases referred to occurred in four houses, the remaining seven cases, regarding which evidence of causal connexion between the fever and consumption of cockles is less trustworthy, involved other four houses."

Cases of typhoid fever in Belfast have been said to be caused by eating cockles collected on the shores of estuaries contaminated by sewage (Otto Jaffé, THE LANCET, Feb. 10th, 1900, p. 421).

Instances of poisoning by means of uncooked mussels have been recorded since 1827 and a number of cases since that date are mentioned by Dr. Bulstrode in his report on oyster culture already referred to. It was formerly thought that this poisoning was due to copper from the docks or from ships' bottoms but this view is not supported by any satisfactory evidence. In 1891 Sir Charles Cameron investigated an outbreak of mussel-poisoning which he considered was due to disease of the livers of the molluscs but it appears much more likely that most, if not all, of the cases of poisoning by mussels are due to sewage pollution.

In his annual report for 1900 as medical officer of health of the London County Council Mr. Shirley Murphy mentions the following instances in which typhoid fever has been mentioned as caused by eating shell-fish in London during the year. "Dr. Sykes refers to an inquiry by him into a localised prevalence of enteric fever in St. Pancras, comprising 57 cases (of which a very few were in Hampstead) and occurring in November in a circle with a radius of three-quarters of a mile. He found that 'a large proportion of those falling ill gave a history of eating mussels from the same source.' Dr. Newman states that in five cases occurring in Clerkenwell 'the only traceable source was the eating of oysters and other shell-fish, procured in each case from a particular stall in a certain street.' Dr. Caldwell Smith states that in six cases in Wandsworth 'the patients had eaten shell-fish within the period of incubation of the disease,' and Dr. Millson, referring to special prevalence of enteric fever in Newington from the middle of September to the middle of November, reports that he came to the conclusion that the disease was due to some article of food and that shell-fish had been eaten by a large proportion of the persons affected. Dr. Kempster states that in a few cases in Battersea patients had consumed shell-fish but that it could not be proved that this had been the cause of the illness. Of cases occurring in Plumstead Dr. Davies writes that eleven cases had within a few weeks of the illness eaten shell-fish. Some of these were in the habit of frequently partaking of molluscs, while others had taken some just about two or three weeks before illness commenced. Five had taken celery shortly before the illness; one was a greengrocer boy and one was a gardener who visited Stratford Market daily. Three of the remaining patients were people of markedly dirty habits."

In Mr. Shirley Murphy's ninth annual report as medical officer of health of the London County Council is a report by Dr. W. H. Hamer on outbreaks of typhoid fever in St. George's, Southwark, Lambeth and Kensal Town in September, 1900. Dr. Hamer showed that the outbreaks were not due to water or to milk-supply or to defective drainage or to the use of a certain swimming-bath, to which the cases in Southwark had been attributed, or to ice-creams, or to any other foods with one curious exception. "The only article of food or drink emanating from one source which had been generally consumed by persons during the outbreak (in Southwark) was *fried-fish*. The circle of a quarter of a mile radius covering the area specially attacked had at its centre a fried-fish shop," and Dr. Hamer showed that "49 per cent., or just about half the families in the portions of the area in which a house-to-house inquiry was made, contained one or more members who ate fried-fish from that shop, and of the whole population of those two areas 48 per cent. did not eat fried-fish, 16 per cent. ate fried-fish not obtained from the particular shop, and 42 per cent. ate fried-fish obtained from that shop." Similar inquiries produced somewhat similar results in Lambeth and in Kensal Town, and in both districts it was noticed that persons attacked by the disease obtained fried-fish from the particular shops, while other members of the household who escaped probably did not. The cause of the cases in Kensal Town was not so clearly traceable, but a number of those attacked purchased fish or shell-fish at a certain general fishmonger's shop. As Mr. Murphy says in his remarks on Dr. Hamer's report: "The question how fried-fish should be capable of conveying the infection of enteric fever is one to which no answer can at present be given. If due to surface contamination before cooking it is probable that this process would destroy the infection; if due to infection within the fish it is improbable that the fish would be sterilised thereby. These points could be determined only by experiment. With respect to the question generally as to how the fish acquired infective property Dr. Hamer found no reason for thinking that specific contamination occurred on the Southwark premises, and if both the Southwark and Lambeth outbreaks were due to the consumption of fish this fact would strongly mitigate against the view that such contamination had occurred in either of these districts, and points to some earlier period at which the fish became infected."

A report by Dr. Turner on an outbreak of typhoid fever in south-east London drew attention to "*ice-creams*" as a possible means of typhoid infection. The occurrence of Italian names among the sufferers led Dr. Turner to ascertain the source from which the makers of ice or ice-creams obtained the milk used in their business. Later he found that 87 per cent. of the patients had eaten ices purchased of itinerant Italians. "The centre about Coldbath-street being fairly compact, it was decided to make a house-to-house inspection there for the purpose of ascertaining the number and ages of the inhabitants, the number of those who ate ices, where the ices were purchased, and whether the fever attacked those who consumed the ices sold by any particular vendor. Seven streets were selected for this purpose. These were adjoining streets, in some of which there were many cases, in some few, and in one there was no fever at all. The result of this inquiry may be summarised thus. The number of inhabitants at all ages in this area was 1551, of whom 627 persons lived in houses in which ices had been eaten and 924 lived in houses in which ices had not been eaten. Of the former (627), 61 had suffered from well-defined enteric fever or diarrhœa, while of the latter (924) who had not been in the habit of eating ices none suffered from such illnesses. The 627 persons in this area who lived in houses in which ices were eaten are divisible into two groups: (*a*) 232, the ices being obtained from shops; (*b*) 395, the ices being obtained from a particular ice-cream vendor whom I will call 'F' and who came from Mill-lane. Of the former (232) none were attacked, but the latter (395) included the whole of the 61 persons who suffered from this illness, and, furthermore, all the 61 persons had actually eaten ices purchased of 'F.' Cases of enteric fever were found to have occurred in at least one house occupied by these Italians before the general outbreak of enteric fever in these districts. In addition, the sanitary conditions of the premises occupied by these Italian ice vendors were very defective. The evidence that enteric fever was distributed by the vendors of ice-cream is therefore very strong. How the ices became specifically contaminated is not, however, very clear, though the possibilities of infection were sufficiently numerous." (*Journal of Public Health*, vol. ix., 1891-92.)

Other beverages besides water and milk have been sometimes proved to be the cause of outbreaks of typhoid fever. Thus a severe outbreak in the Stourbridge Rural Sanitary District (Staffordshire) was investigated and reported on by Dr. Parsons in 1888. It was in a limited area in the townships of Pensnett and Bromley. There was a special incidence of the disease and young adult males employed at ironworks and at other occupations involved especially to heat. The beverage commonly in use by such persons was *ginger-beer*, made often at home from the water of polluted wells and not wholly boiled.

Mr. Spear reported in 1890 that at Pemberton (Lancashire), where there was a smart epidemic of typhoid fever, almost confined to the village of Lamberhead Green, "the village under two separate systems of sewers, each of which embraced districts not affected by the epidemic. Water-supply in use, distributed over a much wider area. Method of excrement disposal (by privy middens) objectionable, but not serving to account for the sudden and widespread of fever outbreak; neither school attendance nor milk-supply implicated. On July 22nd, at the Variety Fair, most, if not all, of the early sufferers drank *ginger-beer*, and ate '*pease-pudding*' that had been made in a room where a child was actually suffering from enteric fever."

In 1898 a case in Westminster was attributed to "*contaminated cocoanut water.*"

Professor Gualdi, Chief of the Bureau of Hygiene in Rome, points out that the seasonal curve of typhoid fever corresponds closely to that indicating the quantities of *raw* *vegetables* sold throughout the different months of the year (THE LANCET, Nov. 24th, 1900, p. 1540).

An account is given of an outbreak *among paying patients* in the Insane Asylum, Northampton, Mass, U.S.A., which had before Sept. 9th, 1899, been singularly free from typhoid fever (only four cases in 10 years), but after that date had 40 cases in about two weeks. Dr. Morse of Massachusetts State Board of Health found that the *paying patients* had *celery* and that the *non-paying patients had not*, and that the celery was watered with filtered sewage; one of the farm servants, acting against orders, ate some of the celery and quickly contracted typhoid fever (THE LANCET, March 17th, 1900, p. 790, from the Springfield *Republican* of Dec. 14th, 1899).

Mr. Francis E. Atkinson, medical officer of health of the Silsden Urban Sanitary District, reported on an outbreak in February, 1891. There were 17 cases, *all children;* the cause was traced to two cases at an earlier date in the latter part of December, 1890. The excreta from these cases had been thrown into an ashpit. "On the 5th and again on the 12th of January a quantity of *decayed fruit*, grapes and oranges (chiefly grapes), had been deposited by a greengrocer upon the same ashpit where the original typhoid excreta had been placed. This fruit was discovered by the children, who were all associated as playmates, and distributed and eaten to a greater or less extent by all of them" (*Public Health*, vol. iii., 1890-91).

In 1871 I was called on to inspect the house at which His Majesty (then Prince of Wales) was supposed to have contracted typhoid fever and I reported the results of my investigations in a letter which appeared in the *Times* of Jan. 22nd, 1872, in which I showed that although there were certain sanitary defects in the house in question there were no such defects as had been previously described. For instance, it had been said that the water-closet in their Royal Highnesses' suite of apartments was directly connected with a cesspool underneath and that its soil-pipe was not ventilated. Neither of these statements was true; there was no cesspool under the water-closet at all, nor, indeed, anywhere on the premises, and the soil-pipe was fully ventilated. There was, in fact, nothing the matter with that water-closet and it is certain that His Royal Highness did not get his attack of fever from any foul air in it. There was, however, a defect in another of the water-closets in the house and I was unable to say positively that the disease had not been contracted there. On looking carefully through my notes, made 30 years ago, I have come to the conclusion that although the outbreak was not caused by water or milk taken at the house it was in all probability caused by some beverage or food (such as oysters or salad) which was partaken of by His Royal Highness, the other gentlemen of the party, and some of the men-servants (perhaps at a shooting luncheon), but not by Her Royal Highness the Princess of Wales or by any of the ladies or female servants; all the other cases were among the gentlemen of the party and the men-servants. Had the outbreak of fever been caused by the insanitary condition of the premises it would certainly have attacked some of those who were most in the house, whereas, as a matter of fact, it attacked those who were most out of doors and some of whom did not sleep in the house at all.

Many outbreaks of typhoid fever have been traced to direct infection from sewer air passing into houses. Among such are the following. In a remarkable report already referred to (see page 36) Dr. (afterwards Sir George) Buchanan showed that the only towns in which the mortality from typhoid fever had but slightly diminished or had even increased after improvement in water-supply and sewerage had been carried out were those in which means of escape for the sewer air were not provided, so that it forced its way into the houses. "But in these four towns (viz., Rugby, Carlisle, Chelmsford, and Worthing) and in no others sewage is received into pumping works at the outfall in such a way that sewer gases are necessarily much confined in the pipes. In the case of Worthing the defect of the outfall arrangement was most serious and in the absence of other exits sewer gases had demonstrably been forced into houses, and outbreaks of typhoid had occurred as the demonstrable result thereof. In the other towns, though to an inferior degree, there were facilities for the same accident occurring. So that it appears that the four towns where fever has not been greatly reduced are so far from constituting an exception to the rule—that removal of organic impurity from the air has been followed by reduction of typhoid—that they even add strongly to the presumption that the rule is absolute and universal." (Ninth report of the medical officer of the Privy Council, 1866.) In another report by Dr. Buchanan on typhoid fever at Croydon he says: "In the course of my inquiry I examined a large number of houses—of course, not a large proportion of the whole, but in a variety of respects typical of the whole—including many where there had been no fever, as well as those where there had been fever, among the latter a probably large proportion where the circumstances of fever production had been most obscure; *and I satisfied myself that in a very considerable majority of the Croydon houses that have had fever drain air charged with infection from the commonest sewers of the town had had the opportunity of entering the houses.* Oftentimes in a group of houses resembling each other in their general sanitary arrangements some particular drain defect was discoverable in certain houses but not in others; and as often it was found that the incidence of the fever had been upon those which showed that drain defect and not upon the houses which did not show it. I quote from among other instances two examples of such differentiation. They were cases of a less common kind, where the relation of the fever to the particular defect had not been at once obvious. **1.** There had been fever at some houses in St. Peter's-street with no inside drains whatever, with outside water-closets and disconnected scullery sinks. The first seven of them were visited and it was found that the drain just outside the house was at four of them practically untrapped, but was efficiently trapped at the other three. In none of the latter had there been fever, but this disease was present last year in three out of the four former. 2. Howard and Birchanger roads, South Norwood, were visited because of a different prevalence of fever in the two. 13 houses in the former road, including seven that had had fever, were examined, and eight houses in the latter, including one of two that had had fever. Few of the houses were found with their drainage arrangements conforming in all respects to the standard, but one particular defect characterised the great majority of those where there had been fever. This was an overflow pipe going direct into the sewer from a cistern that was usually placed in a very confined situation under a bedroom floor. In the Howard-road this arrangement was seen in eight houses, the cistern furnishing more or less of the drinking-water in the case of seven of them and in six out of these seven there had been fever. It was not seen in the five other houses, only one of which (having a stinking water-closet) had had fever. In the Birchanger-road this particular defect was witnessed in two houses only out of the eight visited and one of the two had had a case of fever; the houses where there was no such arrangement had escaped. (Facts as to the second fever house were not obtainable.) Other ways less direct than the foregoing by which excremental products bearing with them the contagium of enteric fever have produced the disease will immediately come under review. But there can, I think, be no doubt that the chief way in which enteric fever spread last year in Croydon was the most direct and commonplace way of all—viz., by the escape of infected air from the sewers and its inhalation by persons susceptible of the disease."

And he adds the following very definite and very important statement: "The great intensity and simultaneousness of the fever epidemic over Croydon should be no hindrance to the acceptance of this view. Where sewers are small and ill-ventilated they constitute perfectly sufficient means for the rapid distribution of fever infection, and places having such sewers may not only show fever-rates maintained as high as before the sewers were made but they may show as smart outbursts of fever as are witnessed where conveyance through water or milk is in question. Croydon itself after it had made its sewers and before it attempted to ventilate them had this experience. So in other instances that have come under my personal knowledge fever has maintained itself after pipe-sewers, ill-ventilated, had been laid, as in Rugby, Carlisle, in Chelmsford, in Penzance, in Worthing, in the last two places breaking out in severe, sudden, and diffused epidemics without there being any question of other distribution than by sewers. And my personal experience is confirmed by that of others. Towns with larger sewers have not appeared to have had the same suddenness of outbreak when spread by means of sewer air has been in question. In them the evil influence of sewer infection is more gradually manifested, as might be expected from the different physical circumstances of the two kinds of sewers."

"While I admit for the most part the sewers of Croydon are well adapted for the removal of liquids and solids, they appear to me to be adapted, when infected by fever excrement, to facilitate the passage of infection into the vicinity of houses. The air of the sewers is, as it were, 'laid on' to houses. It is arranged that every house drain and every house soil-pipe shall contain, up to the very wall of the house and up to the very trap of the water-closet, the common air of the Croydon sewers, not simply charged with impurities it may receive from the particular house but charged also with any dangerous quality that it may have brought from other houses; for hardly anywhere in Croydon can there be found an arrangement for severing the sewer air from the air of the house-drain. So that wherever drain air has entered a house, no matter by how inconspicuous a defect and no matter whether it has given rise to stink or not, it has been the air of the common sewer, and this was throughout 1875 charged to an intense degree with the infection of enteric fever."

After showing that there was "no ground for suspecting that milk has played any part in the epidemic" he gives a number of instances to prove that there were many local contaminations in parts of the water service and continues: "The evidence here adduced respecting the entry of foreign matters into Croydon water-pipes is independent of any view that may be taken as to the mechanism of their entry. Of this mechanism it is difficult for me to speak with any confidence, inasmuch as, even to engineers, the physical conditions of the passage of liquids along tubes are not universally known. It is clear that at Croydon there are some very awkward relations between sewers and drains on the one hand and water pipes on the other. First, the valves through which the sewers are flushed are direct openings from water mains closed by a diaphragm that is liable to leak, and through which it is, to say the least, conceivable that matters may pass from the sewer into the water-pipe on occasions when the water-service intermits. Secondly, the branch mains in particular streets and still more often the service-pipe of particular houses, sometimes lie in the same trench with sewers or house drains; and it is suspected that in places both may be leaking. Thirdly, hundreds of water-closets are served direct from water mains by mere taps on the service-pipes without any interposition of cistern or other safeguard. During times of full water pressure in the pipes these communications may not be hazardous, though as pressure may be taken off a water-pipe by making an opening at the further end of the pipe even more efficiently than by a partial closing of the calibre of the pipe, and as the object of these pipes is to have their further ends opened there is little safety in this consideration. It is no doubt mainly at times of intermission of water service that there arise the physical conditions under which suction of matters from without may take place into the water-pipes, but I have no reason to believe that such accident can take place only at those times." But he finally concludes "*that water pollution played a much less considerable part than was played by infection delivered from the sewers directly into the air of houses.*" (Report of the medical officer of the Privy Council and Local Government Board, New Series, No. VII., for 1875.)

This report of Dr. Buchanan's is especially interesting as in a note to it there are what I believe to be the first diagrams of a disconnecting-trap on a house drain. These are so interesting and important that I have thought it worth while to reproduce them.

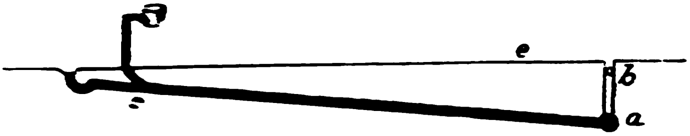
Dr. Buchanan's remarks about them are as follows:—"For the purpose of making the separation between the air of public sewers and of house-drains, an arrangement of the sort figured in the subjoined Diagram II. may properly be substituted for the existing arrangement which is shown in Diagram I.

"Under proper conditions of the public sewers, the trapping bend *(f)* will keep away from the house all air of the common sewer system, and a few houses in Croydon have recently been provided with such a trap. It is most desirable, however, that with every such trap on a house drain there should be associated a ventilator as shown at *g*.

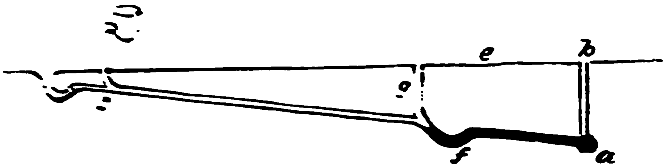
"Such a ventilating opening serves three purposes, (1) if the trap *(f)* be ever forced by pressure of air in the public sewer, an immediate exit of the sewer air away from the house is afforded; (2) a continuous ample ventilation of the house drains is provided,—without such opening the prolonged soil pipe merely affords relief to concentrated and urgent drain air; and (3) a means for inspection of the trap *(f)* is provided, and a way to clean it out if ever it should become choked. It may be observed in Diagram III. the drain from the house to the trap is represented as on a higher level than the drain from the trap to the sewer, a longish piece of sharp slope just before the trap being thus obtained. With this contrivance and in duly proportioned drains stoppage in the trap is not to be greatly apprehended; and, as before said, if it should occur, it can at once be detected and removed.

"The arrangement here shown isolates each set of house drains into a wholly distinct system as shown by the double lines in Diagram II. Even if there should be a little smell from the opening *(g)* it can only be derived from matters that have passed into the drain from the house, and cannot have any

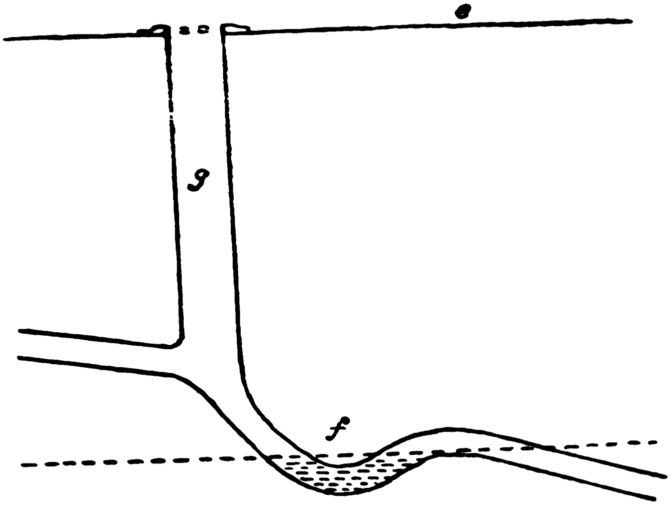
1



II



III



a, Public Sewer.
b, Ventilating shaft of the Public Sewer, habitually more or less blocked by charcoal trays.
a, c, House drain.
d, Ventilating pipe of house drain, now habitually too small and requiring to be of the full calibre of the soil pipe.
e, Edge of house precincts.
f, Trap, and g, ventilator; shown of larger size in Diagram III.

fever infection with it, unless there be fever in the house itself. But in effect (I speak from experience of the arrangement under its most difficult conditions) there is seldom any smell whatever from this opening (*g*), for when the drains are in good order it habitually acts as an inlet for air that goes up the ventilating pipe (*d*) by the side of the house; i the drains are not in good order, there may be smell from this lower opening, and such smell should be welcomed as an indication (otherwise wanting till ill-health occurs) of something about the drains requiring amendment.

"I, of course, leave constructive details to others, not professing to define the mechanical arrangements by which the principles here set forth may be fulfilled.

"It ought to be no objection to this arrangement that the house-drain ventilators (*d*) can no longer serve for the ventilation of public sewers. It is not the business of householders to ventilate public sewers; that is the affair of the authority in whom these sewers are vested. In Croydon the direct connexion between public sewers and the pipes that run up the sides of houses is not only dangerous to the houses, but in relation to public sewer ventilation, the arrangement is little more than a sham."

Dr. F. R. Blaxall reported that in Truro in 1874 an outbreak was caused by "entrance of foul air from the sewers into houses."

Dr. Ballard reported in 1875 on enteric fever at the West Riding House of Correction. He says: "Interior of prison polluted by sewer air in consequence of faulty construction of sewers and drains. Infection probably spread by the use of infected earth supplied to earth-closets."

In the seventh report of the medical officer of the Local Government Board for 1877 is an abstract of a report by Dr. Blaxall on an epidemic of typhoid fever at Padstow in Cornwall, "associated with specifically infected sewer air"—"sewers very insufficiently ventilated and unprovided with means for flushing."

In 1880 Dr. Blaxall reported on an epidemic of typhoid fever in the Urban Sanitary District of Melton Mowbray in connexion with the sanitary condition of that town. He gives a table showing the incidence of the fever on various streets and adds: "It will be observed from this table that on three or four occasions there was a simultaneous appearance of cases in several streets, indicating some cause in special operation over an extended area Thus it soon became possible to exclude, as being primarily concerned, two of the ordinary means of fever propagation—viz., polluted wells and unwholesome privies, the injurious effects of these being limited to persons living in their immediate vicinity or otherwise exposed to their circumscribed operation. In the Melton Mowbray epidemic the invaded families resided in various parts of the town, getting their water from different wells and frequenting different privies. Again, there was no community with regard to milk, some of the infected families not drinking milk at all, others getting it from various sources. On the other hand, the circumstances of the outbreak *reflect grave suspicion upon sewer air as having been mainly concerned in the spread of the disease.* It was found that the several streets which experienced the chief incidence of attacks occupy a portion of the town traversed by one particular line of sewers, and with this line of sewers were connected the houses in which the initial cases occurred and from which, as already explained, the sewer had certainly become contaminated with the specific material of the fever. This suspicion receives confirmation from the fact that all the individuals attacked were found to have been peculiarly exposed to the influence of air escaping from drain inlets or closets. Thus, excluding the initial cases, 23 out of the 36 families had untrapped drain-inlets close to their dwellings; nine had imperfectly trapped inlets which were so offensive that the people used to throw chloride of lime down the drains to stop the stink. Besides this home exposure to the injurious effects of sewer-air the opportunity of similar danger incurred at schools cannot in the case of 14 children be entirely overlooked. Hence it is apparent that out of 36 infected families 32 were exposed to the influence of sewer-air through the medium of untrapped inlets to drains. The remaining four had closets situated out of doors but unprovided with means for flushing—an arrangement conducing to the escape of sewer-air into the closets owing to the traps not being kept duly filled with water. Moreover, the traps of the drains from these houses (like the other 32) were more or less defective" (Eleventh annual report of the medical officer to the Local Government Board, 1881–82).

The prevalence of typhoid fever in the city of York in 1884 was attributed by Dr. H. Airy to sewer air for the following reasons, which I quote verbatim. "The hypothesis that the fever outbreak was caused by sewer exhalations appears to explain the partial distribution of the disease, for the cases in the Micklegate district were almost entirely confined to the area of the Mount sewer, and those on the other side of the river were mainly confined to the Waringate district—that is to the area of the Foss sewers. Moreover, the comparative isolation of the Hungate group agrees with the fact that Hungate forms a distinct subarea of the Foss sewer district. The greater prevalence of the fever in the Micklegate district towards the mouth of the Mount sewer may conceivably be explained by the early occurrence (in February, May, July, and August) of a number of typhoid cases, one of which, imported from Edinburgh, probably introduced new blood (so to speak) into the strain of infection in that line of sewer. The simultaneous infection in Clementhorpe and Layerthorpe in August admits of explanation, I think, only by the state of the sewers, connected as they are below by the river which receives their outfalls, above by the atmosphere with its seasonal vicissitudes."

After considering the suggestion that the fever was spread by a pollution of the ground air and dismissing it because the polluted soil was not in any way specially characteristic of the dwellings in which fever appeared he says: "In conclusion, though under these complicated conditions there is much room for doubt, I am disposed to refer the recent prevalence of typhoid fever in York to exhalations from the ill-ventilated sewers under the influence of an exceptionally dry and warm season" (see also page 129).

The following interesting account is given in *Public Health*, vol. i., p. 319, of an outbreak of typhoid fever produced by sewer air on H.M.S. *Monarch* and described in the Medical Statistical Returns of the Health of the Navy for 1887: "There were four cases in all; three of these appeared to have been undoubtedly attributable to the berth alongside the New Mole at Gibraltar which was occupied by the *Monarch* in January—a situation to which sanitary objections have often been raised. The observations of the medical officer (Fleet-Surgeon Maxwell Rodgers, M.D.) are as follows: 'The *Monarch* arrived at Gibraltar from Lisbon on Jan. 18th and was moored alongside the New Mole at a point nearest the dockyard, where she remained till Jan. 24th, when she left for Port Mahon. Near the south corner of the dockyard and but a short distance from where the ship was moored one of the main sewers of the town empties itself into the sea. During the stay of the *Monarch* at the New Mole a strong wind, which increased to a gale on Jan. 21st, blew in a direction from the opening of the sewer in question towards the ship. A most offensive and sickening smell was complained of by those on board, so much so that some of the officers were obliged to shut their cabin ports in consequence. I am informed that frequent complaints have been made for years past of the insanitary condition of this part of the harbour and that cases of fever have from time to time occurred on board ships moored there and I have no doubt that the noxious emanations from the sewer referred to are quite sufficient to account for the three cases of enteric fever which occurred. Condensed water had been used for drinking and cooking purposes.' The first case occurred on Jan. 22nd, the second on the 29th, and the third on Feb. 6th; this last case was in the person of a young officer who died in the military hospital at Gibraltar. The fourth case occurred at Lisbon in April; the patient, an officer, had visited Oporto. Fleet-Surgeon W. D. Wodsworth, the medical officer of the *Minotaur*, also ascribes two out of the four cases that occurred in that ship to the influence of the same sewer at Gibraltar. He adds that 'its mouth had been damaged so that it was uncovered at low water,' and that he has since heard that 'later in the year [this was in May] some cases of fever occurred among the men of the Rifles who on alternate days supply the Mole guard and were subject to similar conditions, so much so that the guard was discontinued for some time and the drain was mended.' Two men of the *Minotaur* were invalided for the disease." For another case of spread of the disease by sewer air see note on Dr. Wheaton's report on Mold, under heading, "Ground and Ground Water" (page 124).

In 1889 Dr. J. Ashburton Thompson, chief medical inspector of the Board of Health of New South Wales, submitted a report on an outbreak of typhoid fever in the municipalities of Newtown and Macdonaldtown in which he cites cases produced by sewer air, one being produced by the air of an *open* sewer described as follows :—"Over an open sewer in Redfern stood an hotel; there was nothing between the stream of sewage and the air of the house except ordinary joists and ordinary flooring boards which bridged the channel. This open ditch received drainage from the neighbourhood of Well Street, Redfern, taking its origin indeed near" a house where there had been a case of typhoid fever in April. "The tenant, after he had been in occupation no more than nine weeks, reported that a lodger had recently been removed to hospital with typhoid fever and that his daughter, aged 11, then lay ill with the same disease (May, 1886). He also said that he had learned that the tenant before him had recently lost a son there from typhoid. He complained of the smell of the sewer which in favourable states of weather filled the house during the day and always filled it when it was closed for the night. How many other cases may have arisen among casual lodgers in this house of public entertainment there are no means of knowing."

An outbreak of 35 cases of typhoid fever occurring at the Foundling Hospital from Oct. 6th to Dec. 14th, 1891, was investigated by Dr. J. F. J. Sykes, medical officer of health for St. Pancras. He found that fæcal matter from a soil-drain was washed back by the discharge of a flush-tank into a grease-trap into which a discharge pipe from cooking coppers also discharged above the water level, so that the grease-trap acted as an incubator and infected air from it got access to the coppers and to the kitchens; hence the girls employed in the kitchens were mostly attacked—33 girls, two boys. (Special Report and *Public Health*, vol. iv.) I may mention in this connexion that while investigating the causes of an outbreak of cases of diarrhœa and sore-throat at the Hospital for the Paralysed and Epileptic I found that the steam escape-pipes from the cooking ovens were connected with a pipe which joined the ventilating-pipe of a soil-pipe, which also acted as ventilator at the head of one of the main drains, so that when the ovens were cooling foul air from the drains was drawn into them and so into the kitchens.

As instances connected with the washing of clothes I may cite the following. In November, 1900, Dr. R. W. Johnstone, in a report upon an outbreak in Nuneaton and Chilvers Coton Urban District, says: "One case was traced with a good measure of probability to infection derived from the washing of clothes soiled by a fever patient."

At University College Hospital in 1900 an outbreak of typhoid fever occurred among the nurses. I found that it was due to their having been supplied, during the alterations occasioned by the rebuilding of the hospital, with water from a tap which had been newly fixed over a sink in the pantry of their temporary dining-room, this tap having been connected by the plumber with the nearest water-pipe, which happened to be one from a cistern in the water-closet of a ground-floor ward supplying the taps over the vats in which the typhoid linen was placed before being disinfected and washed. When the cistern in question was emptied and cleaned the taps were left open and the typhoid poison obtained access to the pipes and cistern and contaminated the water which next came into it. This is an instance of what Dr. G. V. Poore has called, in his interesting paper read before the Royal Medical and Chirurgical Society on Nov. 23rd, 1897, "pollution at the periphery."

Dr. J. Priestley, medical officer of health of Lambeth, reported in 1900 on an outbreak of typhoid fever limited to three streets. Clothes soiled by urine and fæces of enteric fever patients had been mixed with other people's clothes at mangling houses (THE LANCET, Nov. 3rd, 1900, p. 1289). This outbreak is part of the same one which Dr. W. H. Hamer referred to fried-fish. It is quite possible, however, that both causes may have been at work in the parish.

Dr. Renon (Paris) found that the intensity of typhoid fever in a ward next to a crèche (to which mothers with their infants were admitted) was *much increased*. His explanation was as follows: "Various forms of enteritis are common in the crèche and despite every care it is only natural that the different organisms of infantile diarrhœa exist in enormous numbers both in the crèche and in the adjoining ward. Probably, therefore, typhoid patients suffering from typhoid fever are infected secondarily by microbes from infantile diarrhœa" (THE LANCET, Nov. 10th, 1900, p. 1389).

We now come to the important question of the connexion between the ground and ground-water or subsoil-water with the spread of typhoid fever. In 1856 Professor von Pettenkofer of Munich, having failed to establish any connexion between the prevalence of either cholera or typhoid fever in that city with the drinking-water, commenced his observations on the variations in level of the subsoil water, and he came to the conclusion that the outbreaks, both of cholera and of typhoid fever, occurred during the fall of the subsoil water after considerable rise, and this is graphically shown on the chart which he prepared, a copy of which has been kindly lent to me by Dr. C. Childs. His opinion was that for an attack of one of these diseases three things were necessary—first, the poison of the disease; secondly, a polluted subsoil; and third, ground water falling after a rise. An excellent summary of his views will be found in a paper by Dr. Childs in vol. xvii. of the Transactions of the Epidemiological Society, and a copy of Pettenkofer's Chart in vol. xx. of the same.

Professor von Pettenkofer was so impressed with the immunity of the city of Lyons from cholera, which disease, although it has been introduced several times, has never spread there, that he wrote a paper accounting for this by his ground-water theory, but it must be remembered that typhoid fever was formerly extremely prevalent in that city, whereas by the same theory it ought to have been rare. My belief is that the immunity of Lyons from cholera is due to the fact that the poison has never got at the drinking-water, but that typhoid fever formerly spread there, and sometimes to an enormous extent, on account of the very defective sanitary arrangements, and especially the fact that the cesspools were under the courtyards of the houses and ventilated into the water-closets in the suites of rooms, there being no traps under the basins of the closets, such a method of infection being not only possible but frequent in the case of typhoid fever but being unknown in cholera.

Dr. Buchanan, in a paper which he read before the Society of Medical Officers of Health in the session 1869–70, stated that in his opinion the evidence obtained by Pettenkofer "told in an opposite direction; the question is of two diseases which are more than any others communicable by excremental matter in drinking-water and it is just when soil water is sinking that wells sunk in various soils will furnish impure supplies. The presumption, then, is that the incidence of cholera and enteric fever with sinking soil water is directly operative through the drinking-water supplied by wells." In support of this view Dr. Buchanan's experience furnished him with numerous instances of towns where, a water-supply from external sources having been previously obtained, works which had for one effect a considerable lowering of the soil water were undertaken without any outbreak of enteric fever. While admitting Pettenkofer's theory that subsidence of soil water is a condition favourable to the prevalence of enteric fever he would add this qualification "where the supply of drinking-water is derived from the soil on which it stands." But the decrease of typhoid fever in Munich under von Pettenkofer's advice was so remarkable, as seen by a table also kindly lent to me by Dr. Childs, that it requires special attention. This diminution was produced by the purifying of the subsoil, by making cesspools watertight, by extending the system of sewerage, and, finally, by the sudden abolition of the 800 slaughter-houses in the city in 1878. It is quite obvious that purification of the subsoil must have been attended by considerable purification of the water of the wells by which the town was supplied "until 1883, three years after the epidemic waves had ceased when the high land water-supply was introduced. This supply has gradually been distributed to the whole city." I cannnot help thinking that the drinking water in Munich had more to do with the prevalence of typhoid fever there than Pettenkofer thought was the case.

In the tenth report of the medical officer of the Privy

Council (1867) is an account of Dr. Thorne Thorne's investigation of an outbreak of typhoid fever at Terling, in Essex. This was an epidemic which Sir John Simon describes as follows: "The epidemic at Terling, in Essex, was one of extraordinary dimensions. In that village of only 900 inhabitants, and for the most part within a period of two months, fully 300 persons were attacked with typhoid fever and 41 of the number died. That is to say, the one preventable disease in that short time killed a larger proportion of the population than all causes of death put together ought to have killed there in two years. The conditions which rendered possible this most calamitous visitation of disease were, as in all our other experience, conditions of local filth. At Terling such conditions were at their worst. Round what pretends to be the house accommodation of the tillers of the soil in Terling (a scanty, overcrowded supply of dwellings of the meanest description) every possible source of pollution for air and water was accumulated; the peculiar porous soil which underlay all this filth was, of course, continuously absorbing it; the water-supply of the population was derived from wells, most of them sunk in that excrement-sodden sponge of earth. Some 10 days before the outbreak of the fever, after an extraordinary period of drought, a sudden great rise in the water level of the wells was observed, and this, of course, denoted a long-delayed scouring of that foulest soil into the water-supply of the now poisoned population."

Dr. Thorne Thorne remarks in his report: "The general tendency of the evidence which I obtained is to the effect that the water-supply of Terling was the great infective influence and it will be observed that some of the following cases not only conduce to that general conclusion but also seem very definitely to connect the outbreak of disease with a particular change in the level of the surface (subsoil) water. Everywhere I was informed that the water in the wells had gradually sunk during the latter part of the summer and autumn; in the shallow ones this had been unmistakeably seen, in some of the deep ones I found that the rope holding the bucket had to be let out to an unusual length, and in one instance I was told that after the latter had been lowered into the well such was the scarcity of water that it had to be oscillated to and fro in order to get any in. The date at which the water reached its lowest point varied according to the altitude on which the well was placed and also to its depth. One had been empty two months preceding my visit, a second three weeks; in others the water had been gradually sinking until the latter end of November. Following this drought came a sudden flow of water into all the wells and this, I was informed, took place about three or four weeks before I arrived at the village. In three cases, however, I was enabled to ascertain the exact period of its occurrence and thus to trace out the connexion which it bore to the disease."

Shortly after the water rising again in these wells the outbreak of fever occurred. In explanation of this Dr. Thorne remarks: "It is evident that for years the land springs supplying the village must have washed the foul materials which had soaked through the ground into the wells, although, owing to the water being very abundant, the contaminated solution thus formed was very much diluted. In connexion with this I would call attention to the statement which I have made to the effect that typhoid fever had existed in Terling for at least five years. Recently, however, although the soakage of filth into the ground has been going on there has been a deficiency in the water-supply. That filth must have accumulated until the rising surface water took place, when the whole would naturally be washed from the surrounding ground into the wells and thus give rise to an intensely saturated solution. Great interest, therefore, attaches to the etiological relation which exists between this very severe outbreak of typhoid fever and the state of the water-supply, and it deserves the more notice because the facts observed are not in accordance with those noticed in Munich by Professor Buhl of that city, for the outbreak of the disease did not coincide with the period that the wells were low, but, on the contrary, dated from the time when the water was regaining a high level." (Tenth Report of the medical officer to the Privy Council for 1867.)

Professor Buhl states that with the fall of the ground water typhoid fever makes its appearance in Munich, and that the magnitude of the outbreak depends upon the rapidity of the fall, but that when the water again rises the fever disappears, and this quickly if the water rises quickly, slowly if the reverse occurs (*Zeitschrift für Biologie*, vol. i.).

My friend, Professor Dr. Félix Putzeys, of Liége, has kindly sent me a copy of a report on an epidemic of typhoid fever which occurred at Liége in 1882–83. The outbreak was generally spread over the city, even in many of the best houses. After a careful inquiry the conclusion was arrived at that it was due to infection of the soil by numerous dejections of typhoid fever patients every year and that the germs were transported by the air into houses in the form of dust. The disease was especially spread in houses where the streets are the least cleanly and where the interstices between the stones are wide. Of 30 workers on the pavements no less than 10 had suffered attacks of typhoid fever. Although some of the wells were no doubt contaminated by leakages from cesspools the epidemic was so general that it could not be accounted for in that way.

Sir Charles Cameron attributes the prevalence of enteric fever in Dublin, which city has an excellent water-supply, to foul subsoil, as he considers that defective sewers and drains, many of which, moreover, have been replaced by sound ones, are not sufficient to account for the unusual prevalence of disease in that city. To quote from his own report on the etiology of typhoid fever: "The zymotic death-rate has greatly declined but still typhoid fever more than holds its own. I can only account for this by assuming that the microbes of the disease have established themselves in the soil, that they multiply therein, and that they issue occasionally from it into the atmosphere, which consequently becomes infected. It is only in this way that we can reasonably account for the periodic character of the disease, for its seasonal intensity, for its epidemics. ...... In the soil therefore we must look for the cause of the endemicity of typhoid fever in Dublin and in other places. This theory is greatly strengthened by the fact that the porous soils are to a much greater extent likely to be the habitat of the organism than the stiffer clays. The conditions of existence for all kinds of organisms are more favourable in loose soils than in adhesive dense clays in which air cannot freely circulate. The action of strong winds and the rising and sinking of underground water more readily cause movements of air in gravels and loose soils than in clays, and the escape of microbes from the former under such circumstances must the more freely occur. The streets of Dublin have lately been to a large extent paved with stone setts, which circumstance may, perhaps, account to some extent for the increase of typhoid fever. The underground air cannot now diffuse into the atmosphere over the roadway, and therefore may be drawn in larger quantities into the houses, the basement floors of which are rarely concreted."

In his annual report on the public health of Dublin for 1891 Sir Charles Cameron gave a map showing the distribution of 1988 cases of typhoid fever in that city. He pointed out that on gravel soil the ratio of cases to the population was 1 in 92·8 and on clay 1 in 145·3. Thus the disease is much more prevalent on gravel, as is usually the case. He expresses his belief that these facts appear to show that the organisms that produced typhoid fever escaped into the air more readily from the gravels than from the stiff and usually moist clays.

In a very interesting, though short, report on typhoid fever at Lawrence, Otsego County, New York, in 1891, the cause of the outbreak was described as follows: "We have an epidemic of sudden development, lasting through two months, occurring now at one village and now at another, without a central focus. It occurred in a place having no common source of water-supply, no common system of drainage, and no common distribution of milk or other article of food. It appeared upon an infected site, one in which the disease is regularly recurrent and endemic, and in a locality where typhoid fever is common, other epidemics of severity having within a recent period occurred in neighbouring communities. The factor which determined this fulminant outbreak does not appear upon the surface. That it was one of general application is evident. The only one that can now be cited is in connexion with the soil water and the influence upon it of the unusual drought. This has been sufficient to cause the wells to be low, some of them failing entirely. It is under this condition that the germs dormant in the soil are found to develop into activity. They were supplied from pre-existing cases of past seasons. There is good reason to believe that soakage of these into independent wells, under conditions of soil and of a season of the year especially favourable to developing them, effected a widespread infection of the sources of water-supply and so produced the general and simultaneous occurrence of the disease. That the so-called 'ground theory' of the origin of typhoid fever thus finds expression—by infection of wells over an extended area rather than by pollution of the atmosphere—will, I believe, come to find acceptance." (Thirteenth Annual Report of the State Board of Health of New York.)

In the eleventh volume of the reports and papers of the American Public Health Association for 1885 Dr. C. A. Lindslay, secretary of the State Board of Health of Connecticut, New Haven, gives an account of an outbreak of typhoid fever at Madison, in that State, in September of that year, of which he says: "Indeed, nothing has been found bearing upon the special etiology of this outbreak except an unusually low elevation of ground water. To so marked a degree has the water level fallen that nine-tenths of the wells in the vicinity of the epidemic became dry. This is a measure of drought very much exceeding any previous drought within the memory of the old residents." Dr. J. Jamieson, medical officer of health of Melbourne, maintained at a meeting of the Australasian Association for the Advancement of Science that foulness of the soil from want of a sewerage system had much to do with the great prevalence of typhoid fever in Melbourne (THE LANCET, March 24th, 1900, p. 891).

In 1894 Dr. Wheaton reported on the prevalence of fever at Mold, Flints. This was a remarkable outbreak from the fact that "the occurrence of multiple attacks in households and the association of the outbreak of fever with circumstances of privation among sufferers had suggested the possibility of the disease in question being typhus fever. On inquiry it was found to be typhoid fever. The fever had in all instances occurred in houses where unwholesome conditions existed, chief among which was the *contamination of the soil* around the dwelling by the soakage of filth from open midden steads and from defective drains. The fever was not spread by means of water or milk, but in some instances probably by emanations from defective sewers, in others by means of privies which had become infected by the excreta of sick persons; in others, again, by contagion within households."

In 1895 Dr. G. S. Buchanan reported on the sustained prevalence of typhoid fever at Wycombe Marsh (Bucks). There was no evidence that it was spread by milk or other food. There was no common sewer or public water-supply in the village. The outbreak was not traceable "to water from any one well or group of wells, or to contamination of wells in different parts of the village from any particular cesspool or cesspools," but, on the other hand, there were "indications of specific pollution of the whole body of ground water which supplies the wells of the village."

In 1896 Dr. Bulstrode reported on the continued prevalence of a mild type of typhoid fever at Chichester, Sussex, after the inauguration of a new drainage system and a public water-supply. Dr. Bulstrode showed that the outbreak was not due to the new sewerage or water-supply, as "prior to the introduction of either of these new conditions enteric fever prevailed in a very pronounced fashion in Chichester" and "the localities mainly invaded during 1896 were *those which have been repeatedly invaded in former years*." The evidence showed that "*pollution of the soil* by defective privies and cesspools had operated as principal cause of the endemicity of enteric fever" (Twenty-sixth report of the medical officer to the Local Government Board). In the same year Dr. Bruce Low reported on the continued prevalence of the disease at Middlesbrough, North Riding (Yorks), especially during the previous three years. This endemicity was attributed to the fact that there were "over 3000 privy middens in the town in proximity to dwellings, a continual source of pollution of soil and air of the place, and affording favourable conditions for fostering of filthy diseases like enteric fever. Befoulment of the street surface during the process of emptying the middens constitutes continual source of danger. No suspicion attached to the public water-supply nor to the milk service" (see page 126).

In 1896 Dr. Bruce Low reported on the sustained prevalence of typhoid fever at Southend during many years. He found that there was no evidence of the spread of the disease by public water-supply or by milk service, but that "its persistence was associated with pollution of the porous soil, on which the town is built, by human excrement" (see also under heading "Oysters," page 102).

In the Annual Report on the health of the County Borough of Stockport for the year 1896 Dr. Charles Porter, the medical officer of health, sums up the result of his investigations of the behaviour of typhoid fever in that town during several years as follows :—

"The chief causes of this disease in Stockport are :—

"1. Soil and ground air pollution by soakage of liquid filth from the many enormous foul privy pits which exist.
"2. Soil and ground air pollution by leakage of sewage from defective drains.
"3. Infected dust and emanations from privy pits into which typhoid discharges have been thrown.

"The evils of soil pollution are greatly accentuated by hot dry weather, and in the honest discharge of my duty I must again record the opinion that *the persistence of the midden privy system in your town is a serious and constant source of injury and danger to health, especially in hot weather.*"

In 1897 Dr. Reece reported on the prevalence of "fever" at Aldborough, East Riding (Yorks). This was one of those interesting epidemics in which there were "differing opinions as to the precise nature of the disease which was locally regarded both as Russian influenza and enteric fever." It is reported that "the clinical symptoms point to enteric fever." The first person attacked lived on the highest point of ground in the village. The source of the infection was not traced; nine houses were invaded: 28 persons were attacked and one died. Also a visitor to one of the invaded houses developed a similar disease on her way home and died. The houses were invaded at varying intervals extending over a year. "The order in which these houses were successively attacked followed the direction in which the underground water may be expected to travel from the first house invaded, which was, moreover, not free from the disease for a period of at least five months. A leaking cesspool at the first house invaded received slop drainage from the dwelling. The contents of the cesspool were used on the adjoining garden for manure, as also the contents of the bog-hole privy. The well which was sunk in gravel soil was five feet from the cesspool and 15 yards from the privy. Similar sanitary defects throughout the village."

In 1898 Dr. Theodore Thomson reported on the marked prevalence of typhoid fever during several years in the district of Swinton and Pendlebury (Lancs.). He found that the death-rate from typhoid fever and continued fever during the 10 years 1888 to 1897 was "more than double that in the 33 great towns and two and a half times that of England and Wales during the same period." There was no evidence tending to incriminate water-supply or sewerage conditions. He, however, found evidence from the localisation of the disease that it was associated with filthy conditions such as "unpaved and ill-paved yards, defective house and yard drains and leaky privy middens, all being conditions *conducive to serious fouling of the soil.*" Of this the chief medical officer, Sir Richard Thorne, says in his report: "Well-nigh every possible source of nuisance with which this midden-privy system can be associated has been allowed to grow up, but I would observe that in the face of the knowledge of which this country has been possessed during the past generation such a system must be regarded as nothing short of a relic of ignorance and barbarism which ought not any longer to be imposed on or permitted within civilised communities" (Twenty-eighth Report of the medical officer of the Local Government Board).

In 1899 Dr. Theodore Thomson and Colonel J. T. Marsh reported on the conditions of the city of Chichester, Sussex, which "has on several occasions attracted attention by reason of its liability to repeated occurrences of enteric fever in serious amount" and where Mr. Power, the chief medical officer, says that it "may be considered endemic." After investigating the conditions favourable to the spread of typhoid fever the inspectors said "In our judgment, hypothesis that the prevalence of enteric fever in serious amount in Chichester is referable to the existence there of soil conditions especially favourable to the viability and growth of the infective material of this disease is not inconsistent with the facts ascertained by us and set out by us in this report. But, on the other hand, such hypothesis, while not inconsistent with these facts, does not at present afford adequate explanation of features that have characterised the fever in its distribution in time and place in Chichester. Fuller knowledge of soil conditions in their relations with fever prevalence may account for these features; without that knowledge it is not possible to arrive at definite conclusion" (see also page 125).

The most remarkable instance of the passage of typhoid poison a considerable distance underground occurred at the village of Lausen, near Basle, in Switzerland, and was investigated by Dr. Hägler of Basle (*Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege*, Band vi., S. 154, and sixth report of the Rivers Pollution Commissioners, p. 463). In this previously healthy village, which had never been known to be visited by an epidemic of typhoid fever, and in which not even a single sporadic case of the disease had been observed for many years, an epidemic broke out in August, 1892, which attacked almost simultaneously a large proportion of the inhabitants. About a mile (*viertelstunde*) south of Lausen, and separated from it by the mountain ridge of the Stockhalden, lies the small parallel valley of the Fürlerthal. In this valley lived a farmer, in a solitary farmhouse, who was attacked on June 10th by typhoid fever, just after his return from a long journey. A girl was attacked in the same house on July 10th; and in August the farmer's wife and son sickened of the same disease. There was no communication, so far as could be ascertained, between the farmhouse and the village of Lausen. On August 7th, 10 of the villagers in Lausen were attacked by typhoid fever, and within the next nine days the number of cases had risen to 57, out of a population of 780 living in 90 houses. Within the first four weeks of the epidemic the number of cases rose to 100, and at the close of the epidemic, at the end of the following October, 130 persons—or 17 per cent. of the inhabitants—were attacked, besides 14 children infected in the village during their holidays who sickened with typhoid fever after their return to schools in other places. Except in six houses which were supplied with water from their own wells the cases were pretty evenly distributed throughout the entire village and the above six houses were exempt from typhoid fever. This remarkable fact threw suspicion upon the public water-supply which came from a spring at the foot of the Stockhalden ridge, which is probably an old moraine of the glacial epoch, and such a source might reasonably be regarded as above suspicion of pollution. Observations upon a brook in the Fürlerthal Valley and of the spring at Lausen showed, however, that there was a direct communication between the two. Among the observations it was noted that whenever the meadows—below a hole spontaneously formed 10 years before by the giving way of the soil a little below the farmhouse—were irrigated with water from the Fürler brook the volume of the Lausen spring became greatly increased within a few hours. This irrigation had been carried on during the summer, from the middle to the end of July, the brook being polluted by the typhoid dejecta of the farmhouse patients. It was in direct communication with the closets and dung-heaps of the infected house; all the chamber slops were emptied into it and the dirty linen of the patients was washed therein. It was observed, also, that the water supplied to Lausen was at first turbid, acquired an unpleasant taste, and increased in volume. Three weeks or so after the commencement of the irrigation the epidemic began in Lausen. But Dr. Hägler did not rest satisfied with this evidence and made the following experimental demonstration of the correctness of the assumption that the epidemic was due to the pollution of the Lausen water-supply by the dejecta of the typhoid fever patients in Fürlerthal. The above-mentioned hole in the Fürler valley was opened and the brook led into it; three hours later the fountains of Lausen gave out double their previous delivery of water. A solution of 18 hundredweight of common salt in water was now poured into the hole and soon the Lausen water was found to react more strongly for chlorides than before; the chlorine reaction went on increasing and the proportion of saline matter in the fountains had increased threefold. All doubt as to the passage of water from the fever-stricken Fürlerthal to Lausen being thus removed the question as to whether the water found its way through natural fissures or percolated through porous strata was attempted to be solved by carefully and uniformly diffusing two a half tons of flour through water which was then thrown into the hole. But neither an increase in the amount of solid constituents nor any turbidity of the Lausen water was observed to result from the addition. This experiment, however, in the face of the previously observed turbidity of the fountains whilst irrigation was going on in the Fürler valley is hardly conclusive against the possibility of the water finding its way from Fürlerthal to Lausen by natural conduits. Two things this interesting epidemic does, nevertheless, prove beyond doubt; first, that animal excreta do not, when taken in drinking-water, produce typhoid fever; and next, that typhoid excreta may, when introduced into a water-supply, induce typhoid fever in a distant community when the water in its passage is not freely exposed to the atmosphere (Stephenson and Murphy on Public Health, Vol. I., p. 270).

In *Public Health* for February, 1902, is an important paper by Dr. Edmund M. Smith, medical officer of health of the city of York, on the Incidence of Enteric Fever in York and its Relation to Privy Middens. In this paper he states that for many years past typhoid fever has been endemic in the city of York. In 1900 there was an unusually heavy outbreak which "emphasised the observations and experiences of previous years ...... chiefly that the disease tends to occur in certain midden privy districts." One particular district where there are midden privies and a polluted soil has been the first in the city to be affected in the summer during each of the last three years. It has been impossible to connect the outbreaks in any way either with water or milk, oysters or ice-creams. He suggests that besides the pollution of the soil the poison is carried about by flies and other insects and also by cats, mice, rats, and birds (see also pages 116–7).

Improperly managed earth-closets have in the two following cases been considered to be the cause of outbreaks of typhoid fever. Dr. Ballard reported in 1875 that at the West Riding House of Correction typhoid fever was probably spread by the use of infected earth supplied to earth-closets (Report of the medical officer of the Local Government Board, 1875). I once traced an outbreak among the boys of a union school to improper storage of the compost from the earth-closets which was in a very foul semi-liquid mass under a shed near which the boys (but not the girls) used to play ; there were no cases among the girls.

I have already stated the opinions of some of the most eminent writers on the subject with regard to the question of the communication of typhoid fever directly from one person to another—that is, through the medium of the air—but I will now proceed to cite some instances in which the disease was evidently spread to a considerable extent by means of direct contagion. Dr. W. Budd in his admirable treatise already referred to gives a long account of an outbreak of typhoid fever which he investigated in the village of North Tawton in Devonshire, where he lived and was in almost exclusive possession of the field as a medical practitioner. In the first place he points out that in this village "privies, pig-sties, and dungheaps continued hour after hour to exhale ill odours without any subsequent effect on the public health" and states that he "ascertained by an inquiry conducted with the most scrupulous care that for 15 years there had been no severe outbreak of the disorder and that for nearly 10 there had been but a single case. For the development of this fever a more specific element was needed than either the swine, the dungheap, or the privies were in the common course of things able to furnish. In the course of time, as was indeed pretty sure to happen, this element was added and it was then found that the conditions which had been without power to generate fever had but too great power in promoting its spread when once the germ of fever had been introduced. On July 11th, 1839, the first case of typhoid fever occurred in a poor and crowded dwelling. Before the beginning of November in the same year more than 80 of the inhabitants had suffered from it under my care." He then describes the course of the outbreak, showing quite clearly over and over again that one person contracted the disease from another. Later in his book, after having mentioned some other outbreaks and quoted various authors to prove that the disease is contagious, he refers to North Tawton again as follows: "About two years ago—i.e., in 1873—after an interval of 30 years' almost entire immunity this town was again visited by typhoid fever. Meanwhile a water company had been established by means of which drinking-water, brought from a considerable distance in iron pipes, is delivered under high pressure to every inhabitant. Contamination of this water by human excreta is an absolute impossibility, and yet in these two outbreaks of typhoid the population suffered even more severely than before. In the course of a few months out of a population of 1500 persons 120 were known to have had typhoid fever and 11 of their number died." He considers that in this and in some other epidemics which he describes "the air was the great medium through which the infection passed." His final opinion as to the relative importance of water and air as media for communication of the poison of the disease is stated as follows: "The exact proportion which the cases caused by infected water bear to those caused by infected air is not easy to determine and probably varies much under different conditions of soil, climate, season, water-supply, social habits, and sanitary arrangements. As far as my own experience goes I can state that the worst and most widespread outbreaks which I have ever witnessed occurred in communities where the drinking-water was absolutely blameless."

In the twenty-fourth annual report of the State Board of Health of Massachusetts for 1882 Dr. William T. Sedgwick, after attributing the epidemics at Lowell and Lawrence to polluted water, reports on three epidemics in Bondsville, Provincetown, and Milleville, each of which he attributes to "secondary infection," having excluded infection by means of water and milk. He gives a graphic account of the way in which the poison of the disease gets handed about, and says, "It is easy for me to understood how dirt, diarrhœa, and dinner too often get sadly confused. Personal filth is apparently the principal agent of secondary infection." Of the epidemic at Milleville he says, "The high mortality was probably due not so much to the severity of the disease as to utter neglect and dire poverty. The local conditions were very bad, and the people were mostly very poor. The circumstances favoured the spread of the disease by secondary infection, and to that, in my opinion, the epidemic was almost wholly, if not entirely, due."

As an instance of direct contagion I may mention that Dr. H. F. Parsons reported on an outbreak of typhoid fever at Bedlingtonshire (Northumberland) when there was endemic prevalence of the disease in a colliery district in 1889. He found that most of it was referable to "a case which occurred in a close, confined, and filthy part of Bedlington town. The disease first spread to other families living in tenements under the same roof and then in the neighbouring streets, where want of air-space, privy and drain nuisances, and general want of cleanliness prevailed." Dr. Parsons reported in 1892–93 on a severe but circumscribed outbreak of typhoid fever which occurred at Newfield Moira (Leicestershire) extended over two months and was limited to two rows of houses. The first cases were possibly contracted in Burton-on-Trent. The spread of the fever was not due to polluted water or milk nor to defects of drainage or common use of privies but was "probably due to direct contact with specific infection favoured by common use of wash-houses, foul state of unpaved yard, and careless habits of mining population."

In the same year Dr. R. D. Sweeting reported on an outbreak at Temple Cloud, Cameley parish (Somerset). In this district the early cases were "associated with grossly unwholesome circumstances of water-supply and excrement disposal," but the later cases were "probably directly infected from the earlier owing to non-disinfection of stools." (22nd Ann. Rep. Med. Off. L. G. B.)

In 1889 Dr. J. Ashburton Thompson, chief medical inspector of the Board of Health of New South Wales, submitted a report on an outbreak of typhoid fever in the municipalities of Newtown and Macdonaldtown, in which he gave a number of "examples of the spread of typhoid by the pollution of air." In the first example a woman suffering from the disease introduced the poison to the cesspit of a certain house which was generally in a very insanitary condition and the disease spread among that family. On their removal to another house in another street, also in a very filthy condition, they conveyed the poison there and the disease spread in that family also. The second example was very like the first, the filthy surroundings of the house "did not, as far as was ascertainable, cause disabling illness until the first case of typhoid fever had been produced by outside contagion; when that patient had nearly recovered it began to spread through the household rapidly." The other cases are somewhat similar.

Dr. Sweeting reported in 1893 on a localised outbreak of typhoid fever occurring during the first four months of the year on the outskirts of the town at Amlwch (Anglesea). He found that there was no common water-, milk-, or food-supply, and no drainage, but that the "disease spread from an imported case amongst tenants and visitors in the absence of proper nursing, isolation, and disinfection." (23rd Ann. Rep. Med. Off. L. G. B.)

In 1895 Dr. S. W. Wheaton reported on a remarkable outbreak of typhoid fever at Quarry Bank (Staffordshire). This outbreak was almost entirely confined to a small portion of the district and especially to one particular street. "This marked localisation of the fever and the fact that it had in some instances affected nearly all the members of certain families, suggested the presence of some fever (e.g., typhus fever) more directly contagious from person to person than enteric fever. The fever in question was found to be undoubtedly typhoid fever. The water-supply was in most instances from draw-wells subject to pollution by leaking privies, defective drains, and by surface washings." The spread of the disease was "probably in part due to polluted water, partly to privies which had become infected, and to *personal contagion*." (The italics are mine.)

In 1895 Dr. H. T. Bulstrode reported on an outbreak occurring at Potterspury (Northamptonshire) which commenced in July and was still continuing at the date of the report in November. The evidence pointed to "polluted well water as a very important factor in causation, *though personal infection had probably considerable influence in the spread of the disease*." (The italics are mine.)

In 1896 Dr. G. S. Buchanan reported on the continued prevalence of typhoid fever at West Bromwich (Staffordshire) for several years. In 1895 there was a heavy incidence of the disease on three small areas widely separated one from another. The prevalence of the fever was "referred to the many opportunities of local spread from patients or invaded premises afforded by sanitary defects and by want of isolation hospital accommodation." (25th Ann. Rep. Med. Off. L. G. B.)

Dr. J. Priestley, the medical officer of health of Lambeth, in 1898 reported that in that parish in three instances typhoid fever was conveyed from person to person during nursing.

In 1899 Dr. S. M. Copeman reported on an outbreak at Shirebrook village (Derbyshire) that the disease was "*mainly spread by personal contact*, though in addition there appeared reason for suspecting that the milk-supply was concerned in causing extension of epidemic."

In August, 1900, Dr. Copeman reported on an inquiry into the continued prevalence of typhoid fever at Shirebrook, in the Blackwall Rural District, on the borders of Nottinghamshire and Derbyshire. He found "that the annual recurring outbreaks of typhoid fever in Shirebrook have been in large measure dependent upon the polluted condition of the subsoil in the lower portions of the village arising from the impossibility of securing efficient isolation in the cottages. In the newer colliery village, situated as it is on considerably higher ground, typhoid fever had not made its appearance before 1899. In this portion of Shirebrook also the disease was undoubtedly spread by personal infection, although in addition question arose as to whether the consumption of infected milk may not have played a part in the extension of the disease." (29th Ann. Rep. Med. Off. L. G. B.)

In his annual report for 1900 as medical officer of health of the London County Council Mr. Shirley Murphy gives the following cases of infection from one person to another in different districts in London: "Dr. Reginald Dudfield observed this in four instances; Dr. Parkes shows the extension of the disease in Chelsea from one person of a family to seven others; Dr. Sykes gives account of two households in St. Pancras, in one of which the first case of the disease was followed by six others, and in the second by nine others; Dr. Newman connects directly or indirectly nine cases in Clerkenwell with one or other of three cases occurring among children attending the same Sunday school; Dr. Bryett gives particulars of six series of such cases occurring in Shoreditch; Dr. Kempster attributes a group of cases occurring in a street in Battersea to the same cause; and Dr. Bond mentions two nurses who were infected while in attendance upon cases of the disease."

An important paper was read before the Epidemiological Society in 1900 as an introduction to a discussion on the Infectivity of Enteric Fever by Dr. E. W. Goodall, medical superintendent of the Eastern Hospital of the Metropolitan Asylums Board. Dr. Goodall, who has had exceptional opportunities of studying the disease, has come to the conclusion that, contrary to the opinion of many high authorities, the view held by Bretonneau, Trousseau, Gendron, Piedvache, Budd, Sir Thomas Watson, and Dr. Alexander Collie, the former medical superintendent of the Homerton Hospital, that the disease is directly infectious from one person to another is the correct one. He insists on the frequency with which those in attendance on the sick catch the disease, produces a number of instances of this having taken place among the nurses of the Metropolitan Asylums Board Hospitals, states that "enteric fever has attacked the staff in the three newest hospitals of the Asylums Board—the Brook, the Park, and the Grove," and adds: "Concerning the 10 cases at the Brook Hospital Dr. J. MacCombie has kindly informed me that five of them occurred in the persons of nurses working in the enteric fever wards, including an assistant nurse who came straight from the Broughton Sanatorium where she had been nursing enteric fever patients, and who joined the Brook Hospital during the incubation stage of the disease, while of the other five, two were men whose duty it was to keep the floors of the enteric fever wards polished. With respect to the three cases at the Grove, the most recently erected hospital, I am indebted to Dr. J. E. Beggs for the information that they were two assistant nurses and a wardmaid, all of whom for nearly two months had worked in enteric fever wards. It was the duty of the wardmaid to carry the soiled linen to the tank." He agrees with Dr. Collie's opinion, "that if enteric fever amongst the staff of a hospital is to be attributed to faulty sanitary arrangements, especially in connexion with the drainage, we should find the disease occurring more frequently amongst the patients who are not suffering from the fever than appears to be the case." With regard to the fact that other patients do not, as a rule, catch typhoid fever from patients suffering from that disease (although I am satisfied that they occasionally do so), he points out that it is rare, even for typhus fever, which everybody deems to be highly infectious, to be caught by one patient from another in a fever ward, and he concludes; "Personally I am strongly inclined to side with those who hold that enteric fever is much more readily and directly communicable than is commonly supposed."

In the discussion which followed, Dr. F. Foord Caiger, medical superintendent of the South-Western Hospital, stated that the contagiousness of typhoid fever to those "who are in the daily administration of a fever hospital into which enteric fever is admitted has become a matter of conviction," and he stated that in the South-Western Hospital, "in the course of nine years during which enteric fever has been admitted there, 23 members of the staff have contracted it and three of them have died. Of these 23 members every one was a nurse and, with one exception, every one of these nurses was nursing in the enteric fever wards. When you consider that the proportion of enteric fever nurses to the whole of the nursing staff is only like one in 15 this fact is very striking."

Dr. Bulstrode is of opinion that "the view is certainly gaining ground that enteric fever is more directly communicable from the patients to the nurses and attendants than was formerly supposed."

Dr. Alfred Hill and Dr. Niven, the medical officers of health of Birmingham and Manchester, are of the same opinion. The latter traced 53 cases out of 484 to direct infection, and says, "it is also necessary to remember that, given certain conditions, such as crowding in a household, typhoid fever is terribly infectious," and he gives three remarkable instances, one being that of a number of nurses in a public institution among whom it was introduced by one of their number and who took it from one another, as he was able "at once to dismiss the water and milk and also any condition affecting the drainage of the wards." None of the patients in the institution took it. (*Public Health*, vol. iv., p. 202.)

Dr. P. Manby quoted an interesting instance of communication of typhoid fever from one person to another in a hotel; and Dr. Franklin Parsons, the President of the Society, one of the medical inspectors of the Local Government Board, gave several instances in his own experience in which, after careful investigation, "personal communication seemed the only agency" to which the disease could be attributed; and as the result of his great experience Dr. Goodall says: "I am quite sure that those are wrong who teach ...... as is evidently taught by the leading text-books ......, that there is no risk in nursing typhoid fever patients and that there is no necessity for removing an enteric fever patient from his home to hospital." In fact, the result of this discussion showed that there was great unanimity of opinion, not only among the inspectors of the Local Government Board, but among medical officers of health throughout the country, that communication by direct contagion is a much more common cause of the spread of typhoid fever than is commonly supposed.

We now come to the consideration of the actual poison of the disease. I will first give you Mr. (afterwards Sir John) Simon's views in his own words. He said in his supplementary report for 1873, "While, however, thus far there is only the familiar case of the so-called *common chemical poison*, which hurts by instant action and in direct proportion to its palpable and ponderable dose, the other and far wider possibilities of mischief which we recognise in filth are such as apparently must be attributed to *morbific ferments* or *contagia*, matters which not only are not gaseous, but on the contrary, so far as we know them, seem to have their essence, or an inseparable part of it, in certain solid elements which the microscope discovers in them—in living organisms, namely, which in their largest sizes are but very minute microscopical objects, and at their least sizes are probably unseen even with the microscope, organisms which, in virtue of their vitality are indefinitely self-multiplying within their respective spheres of operation, and which, therefore, as in contrast with common poisons, can develop indefinitely large ulterior effects from first doses which are indefinitely small.

"As, apparently, it is by these various agencies (essential and incidental) that filth produces 'zymotic' disease, it is important not to confound them with the fœtid gases of organic decomposition, and the question what infecting powers are prevalent in given atmospheres should never be regarded as a mere question of stink. It is of the utmost practical importance to recognise in regard of filth that agents which destroy its stink may yet leave all its main powers of disease-production undiminished. Whether the ferments of disease if they could be isolated in sufficient quantity would prove themselves in any degree odorous is a point on which no guess need be hazarded, but it is certain that in doses in which they can fatally infect the human body they are infinitely out of reach of even the most cultivated sense of smell, and that this sense (though its positive warnings are of indispensable sanitary service) is not able, except by indirect and quite insufficient perceptions, to warn us against risks of morbid infection."

And further, in the same report: "It must be remembered that gases on the one hand and the particulate ferments on the other stand in widely different relations to air and water as their respective media of diffusion. The ferments, so far as we know them, show no power of active diffusion in dry air, diffusing in it only as they are passively wafted and then probably, if the air be freely open, not carrying their vitality far, but as moisture is their normal medium currents of humid air (as from sewers and drains) can doubtless lift them in their full effectiveness, and if into houses or confined exterior spaces then with their chief chances of remaining effective; and ill-ventilated low-lying localities, if unclean as regards the removal of their refuse, may especially be expected to have these ferments present in their common atmosphere as well as, of course, teeming in their soil and ground water. Considerations like some which I have stated in regard of infective air apply equally to infective water. In the latter, just as in the former, the zymotic malignity is but indirectly and most imperfectly suggested to us by qualities which strike the common sense, or by matters which chemical analysis can specify. As any unbrutalised sense of smell will turn with disgust from certain airs, so will it, and common taste and sight, be repelled by certain waters, and as the chemist can show certain foulnesses in the one, so he can show certain foulnesses in the other; but these tests, it must always be remembered, are tests only of the most general kind. Confessedly they do not touch the *corpus delicti*, but only certain conditions to which it is or may be collateral; and their negative findings are consequently not entitled to the same sort of confidence as their positive. Chemical demonstration of unstable nitrogenous compounds in water is a warning which of course should never be disregarded; but till chemistry shall have learnt to identify the morbific ferments themselves, its competence to declare them absent in any given case must evidently be judged incomplete, and waters which chemical analysis would probably not condemn may certainly be carrying in them very fatal seeds of infection."

Mr. Simon continues: "Since the year 1849, when Dr. (now Sir William) Jenner made known his conclusive and masterly discrimination of this specific form of fever, successive studies have tended with singular uniformity to connect it in regard of its origin with nuisances of an excremental sort.[1] In illustration of that fact in the natural history of enteric fever I may refer to an abstract which I append of the experience of the Medical Department during the four years 1870–73 in this particular branch of disease-production, and such illustrations might be multiplied to any desired extent. The experience is, not only that privies and privy-drainage, with their respective stinkings and soakings, and the pollutions of air and water which are thus produced, have in innumerable instances been the apparent causes of outbreaks of enteric fever, but, further, that they have seemed capable of doing this mischief in a doubly distinctive way; first, as though by some aptitude which other nuisances of organic decomposition, though perhaps equally offensive, have not seemed equally or nearly equally to possess; and secondly, as though this specific property, so often attaching to them in addition to their common septic unwholesomeness, were not, even in them, a fixed property. The explanation of this experience, the explanation of the frequent but not invariable tendency of privy nuisances to infect with enteric fever, has seemed to consist in the liability of such nuisances to carry with them, not invariably, but as frequent accidental adjuncts, the 'specific' contagium of any prevailing bowel-infection, for presumably the privies of a population receive (*inter alia*) the diarrhœal discharges of the sick; and it has long been matter of fair pathological presumption that in any 'specific' diarrhœa (such as eminently is enteric fever) every discharge from the bowels must teem with the contagium of the disease. Medical knowledge in support of this presumption has of late been rapidly growing more positive and precise, and at the moment of my present writing I have the gratification of believing that under my lords of the Council it has received an increase which may be of critical importance in a discovery which seems to give us for the first time an ocular test of the contagium of enteric fever; in the discovery, namely, of microscopical forms, apparently of the lowest vegetable life, multiplying to innumerable swarms in the intestinal tissues of the sick, penetrating on the one hand from the mucous surface into the general system of the patient, and contributory on the other hand, with whatever infective power they represent, to the bowel contents which have presently to pass forth from him" (Report of the Medical Officer of the Privy Council and Local Government Board, New Series, No. II., 1874).

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[1] "The very able writings of Dr. Murchison, dating from a paper by him in the Medico-Chirurgical Transactions of 1858, have been of particular influence in that contention."

The investigations referred to by Mr. Simon were those made by Dr. Klein, and described in his report on the Intimate Anatomical Changes in Enteric, or Typhoid, Fever. (Report of the medical officer of the Privy Council and Local Government Board for 1874; New Series, No. VI.). In this report Dr. Klein described the changes in various organs in typhoid fever, giving a number of plates in illustration of these changes, and also described certain organisms found in the intestinal mucous membrane and some other organs in the early stages of the disease. After this other observers described various organisms found in the organs in fatal cases of typhoid fever, especially Klebs who announced the discovery of a long thread-like bacillus which he considered to be the cause of the disease, and in 1880 Eberth discovered the rod-shaped organism now known by his name as Eberth's bacillus, or the bacillus typhosus. It appears, however, that before Eberth's paper appeared Koch had found in about half the number of cases examined by him typical colonies of short bacilli precisely similar to those afterwards described by Eberth. It would appear, therefore, that Koch first discovered the true bacillus typhosus, although his name has not become associated with it. This bacillus was subsequently investigated by Dr. Gaffky, whose paper was published in the *Mittheilungen aus dem Gesundheitsamte*, vol. ii., 1884, and a translation of it by Dr. Pringle was published by the New Sydenham Society in its volume for 1886. Dr. Gaffky examined the organs of 28 fatal cases of typhoid fever and found the typical bacillar masses in 26 of them. He says: "My results agree entirely with the descriptions given by Eberth, Koch, and Meyer in regard to the shape and appearance of the bacilli. On the average they are about thrice as long as they are broad; their length corresponds to about the third part of the diameter of a red blood corpuscle. In isolated spots one may see somewhat longer threads which on more thorough examination can, however, be seen to be made up of several members. Trifling differences in breadth occur even in different cases in the same epidemic, but this appearance is to be referred only to the greater or less intensity of the staining of the sections; at least, I have never been able to observe it in preparations on cover-glasses in which the staining is always deep; the extremities of the bacilli are distinctly rounded off. In several of the cases I examined the bacilli found in the internal organs contained unmistakable spores which appeared as round portions, remaining unstained, and occupying the whole breadth of the bacilli."

In discussing the question as to whether these typhoid bacilli are specific pathogenic organisms he says: "If I range myself on the side of those who consider the typhoid bacilli as specific organisms and their origin from putrefactive bacilli as at least very improbable it is upon the following grounds. In almost all the cases of typhoid fever which I have examined, whether they came from Berlin hospitals, from St. Petersburg, or from Wittenberg, there was always present a definite form of rod-shaped organism in the internal organs, arranged in quite a characteristic manner, and undoubtedly the same as had previously been observed at various times and in various places by Eberth, Koch, Meyer, and C. Friedländer. Anatomical examination gives us not the slightest ground for thinking that these bacilli had anything whatever to do with putrefaction. To all appearance they did not proliferate after death, as one does not find that the masses are at all more numerous or larger in cases in which putrefaction has already set in than in those examined as soon after death as possible. Further, in an organ removed as early as possible from the body, although it may contain ever so numerous masses of bacilli, all coarse signs of commencing putrefaction perceptible to the senses are wanting. In the same way the microscopic appearance of the tissue presents nothing suggestive of that process. The nuclei in the vicinity of the masses stain rather exceptionally deeply with aniline stains, whilst the bacilli themselves (apart from the conditions found in the intestine) always form limited masses and never permeate the organ in all directions, as we are accustomed to see in the case of putrefactive bacilli. I would also adduce as a very weighty argument against the view that typhoid bacilli have any connexion with putrefaction the fact that when cultivated outside the body they never become causes of putrefaction, as far as my researches permit of a judgment. I have carried out a great number of cultivations in succession with those derived from 13 different cases and the bacilli never produced putrefaction in substances extremely liable to putrefaction in spite of their luxuriant growth. Even when cultivated outside the body for more than a year nothing of the sort has occurred. As the bacilli always form the same masses in the internal organs, whether one examines fatal cases of typhoid fever in Russia, Germany, Switzerland, or England, so in the same way, cultivated outside the body on the same nutrient matter, they have hitherto always displayed the same manner of growth and the same mode of spore development, whether I obtained the cultivations from typhoid organs in Berlin or from the Wittenberg epidemic."

M. A. Rodet and M. G. Roux (of Lyons) consider that there are intimate relations between the bacillus coli and Eberth's bacillus; that the latter is, in fact, the former "in a state of attenuation or degeneration"; they "think that the bacillus coli becomes virulent, *typhigenic*, without notably changing botanical characters; and that it is within the organism, notably in the spleen, that it takes the type of the bacillus of Eberth, degenerating no doubt under the destructive acts of the organism." And they add: "It is not necessary to insist on the consequences which these facts entail relative to prophylaxis, it is not only typhoid fever dejections, but fæcal pollution of any kind which may engender typhoid fever."[2] This would have delighted Murchison's heart but it is a view which has not been generally accepted.

For a detailed description of the characters and methods of isolating and cultivating the typhoid bacillus I only need refer you to Dr. P. Horton-Smith's excellent Goulstonian Lectures,[3] delivered in this College in 1900, but I wish to refer more particularly to a specially interesting account given in those lectures of the persistence of the typhoid bacillus in the body, especially in the bile or the bone-marrow, where it has been now shown it may remain for years. Dr. Horton-Smith quotes some cases from a paper by Hunner in the *Johns Hopkins Hospital Bulletin* for August and September, 1899, as follows: "In one case the bacilli were found in pure culture in the inflamed gall-bladder three months after the fever, in another eight months, and in a third after an interval of seven years." The most remarkable case of all, however, and one very carefully tested, is that recorded by von Dungern (*Münchener Medicinische Wochenschrift*, 1897, p. 699) in which 14½ years after the attack of typhoid fever the bacilli were still present in pure culture in the pus, and Dr. Horton-Smith very well adds: "Truly no longer can we say with Dr. Budd, that 'by destroying the infectious power of the intestinal discharges the disease may be in time finally extinguished.' So far, indeed, from the stools being the only agents by means of which the disease is spread they are but one of a series of agents. So far, too, from the patient ceasing to be a source of danger after his restoration to seeming health, he may carry about in himself the seeds of infection for months and even years."

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[2] Public Health, vol. ii., 1889-90 (from Comptes Rendus de la Société de Biologie, tome ii., No. 7, February, 1890).

[3] THE LANCET, March 24th (p. 821), and 31st (p. 910), and April 14th (p. 1050), 1900.

A useful account of the tests used for discriminating between bacillus coli and bacillus typhosus was given by Dr. A. C. Houston in introducing a discussion on Typhoid Fever in its Public Health Aspects at the Cheltenham meeting of the British Medical Association and will be found in the *British Medical Journal* of August 17th, 1901.

Dr. Klein made an investigation on the Eberth-Gaffky bacillus which is described in the report of the Local Government Board for 1892–93. He could not find the bacillus in the blood of the living typhoid fever patient but in certain tissues of the bodies of those who had died from the disease he never failed to find it, especially in the mesenteric glands and in the spleen, and he describes its differences from the bacillus coli. The next year he reported that he had made experiments with this bacillus on monkeys. Two monkeys to whose food had been added a culture of the typhoid bacillus did not suffer in any way; no pathological lesions were found in them after they were killed, neither could the typhoid bacillus be detected in their blood or spleen. On the other hand, eight monkeys having been inoculated with cultures of the bacillus the true typhoid bacillus was found in abundance in the spleen of one of them, the bacillus coli in that of another, and "a nondescript bacillus exhibiting characters pertaining some of them to bacillus coli, others to the typhoid bacillus" was found in a third. In inoculated calves the juice of the enlarged inguinal glands was always found to contain the typhoid bacillus in abundance. The next year Dr. Klein demonstrated that under certain conditions the typhoid bacillus readily multiplies in sewage, "while as regards drinking-water he shows not only that in many different waters this bacillus may persist longer than has hitherto been demonstrated, but also that in certain of them which are to be thought of as affording pabulum for the microbe the typhoid bacillus is able on occasion to proliferate in abundant fashion."

With regard to the relative frequency of the *bacillus typhosus* in the intestinal discharges and in the urine I may quote the following important communications, which threw a new light on that question.

In a paper entitled "Etudes sur la Fièvre Typhoïde Experimentale" published in the *Annales de l'Institut Pasteur* for April, 1894, by Dr. Joseph Sanarelli of Rome, among the conclusions drawn from his researches, which were carried out in the laboratory of Professor Metchnikof at the Pasteur Institute are the following :—

"In experimental typhoid fever as in human typhoid fever the bacilli of Eberth are not ordinarily found in the contents of the intestinal canal. This the more confirms the fact that the intestinal lesions peculiar to this disease have an excessively toxic origin, and that removes all value from the old idea according to which typhoid fever should be considered as a process infectious in origin and with intestinal localisations."

"This absence of the bacillus of Eberth in the intestine of man or animals is explained by the two following reasons. 1. Because typhoid fever is only an affection of the *lymphatic* system. It is there alone that the virus is localised by preference, multiplies, and produces its poison. 2. Because as soon as this poison has made its influence felt on the intestinal walls in determining the commencement of the grave anatomical and functional changes already described, the *bacillus coli* of the intestinal canal becomes pathogenic, multiplies to an extraordinary extent, and tends to become the sole representative of the intestinal flora by annihilating the other species of microbes."

In the same *Annales* for April, 1895, is a paper by Dr. A. Wathelet of the University of Liége, on the bacteriological examination of the intestinal discharges in typhoid fever. He points out that Gaffky himself had acknowledged that it was almost impossible to find in the intestinal discharges the specific bacillus which is found in the spleen, and explained this by the difficulty of finding that bacillus in the midst of the intestinal saprophytes.

The result of Dr. Wathelet's experiments was that "in 600 colonies collected from typhoid stools and having characters common to the *bacillus coli* (transparent variety) and to the *typhoid bacillus*, the latter was only found ten times. Many patients did not yield the *bacillus typhosus* on any one occasion."

"What a difference," he remarks, "from the almost pure cultures of the specific microbe which one sometimes finds in cases of cholera! It must be confessed that this extreme rarity of the bacillus of Eberth in the intestinal canal conforms badly with the current theories of typhoid fever, and that one explains the facts better by considering with M. Sanarelli that in this disease the microbe at first attacks the lymphatic system (spleen and mesenteric glands) and is only found accidentally eliminated in the discharges on the other side of the intestinal walls."

"We have in these researches again found the facts so often observed, viz., that at the autopsy the digestive canal is found filled with *bacillus coli* to the exclusion of the *bacillus typhosus*, whilst it is just the opposite for the spleen."

These papers were followed by one published in the LANCET of July 27th, 1895, by Dr. A. E. Wright, Professor of Pathology in the Army Medical School, Netley, and Surgeon-Major D. Semple, Assistant Professor of Pathology in the same school, "On the presence of the typhoid bacillus in the urine of patients suffering from typhoid fever."

After referring to and commenting on the papers from which I have just quoted they give the results of the examination of the urine of 7 cases of typhoid fever as follows:—"We thus see that in 6 out of 7 cases examined the typhoid fever bacilli were easily detected in the urine. In view of this fact it seems to us that the bacteriological examination of the urine ought not to be neglected in any doubtful case in which typhoid fever is suspected. It is hardly necessary to do more than merely advert to the hygienic aspect of the matter. It was only a natural outcome of the intestinal intoxication theory of typhoid fever that the greatest precaution should have been enjoined with regard to the stools of the patient suffering from typhoid fever, while the disinfection of the urine was neglected. If, however, the recent observations on the almost constant absence of typhoid fever bacilli from the stools are to be trusted, the disinfection of the fæces will have to rank not as an article of faith, but as a mere 'counsel of perfection.' On the other hand, the most careful attention will have to be given to the disinfection of the urine. In some cases the urine even before incubation is absolutely turbid with typhoid bacilli."

Dr. Edmund Cautley made a research on the behaviour of the typhoid bacillus in milk and his account of it will be found in the report of the medical officer of the Local Government Board for 1896-97. He found that in unsterilised milk to which the typhoid bacillus was added it was recovered in considerable numbers from the milk which had been kept for six or seven days and had turned completely sour; and in sterilised milk to which the typhoid bacillus and some other microbes were added he found that the typhoid bacillus will live in the presence of the bacillus lactis for a week but will not actually multiply under these conditions. He says "that the presence of the oïdium lactis in sterilised milk does not interfere with the growth and multiplication of the typhoid bacillus" and that yeast did not interfere with the growth of the typhoid bacillus, as "both micro-organisms increased in number and neither appeared to be modified in its growth by the presence of the other." He considers that "the typhoid bacillus will live in milk under conditions which ordinarily prevail in a household. When this bacillus has been artificially added in large amount to milk in the condition in which it commonly reaches the consumer the presence of the microbes *in the living state* may be demonstrated after the milk thus treated has been kept for several days. There is no indication from the above investigations that this microbe is capable of multiplication under the conditions in question. Judging from the results obtained it is very probable that the number present rapidly diminishes in milk which is kept." The observations with regard to the bacillus lactis and to sour milk "indicate that it is quite possible for the typhoid bacillus to exist in curd-cheeses."

In a report by Dr. Klein on the behaviour of certain pathogenic microbes in milk, cream, and cheese he says: "It is well known that the typhoid bacillus grows luxuriantly in milk both at 20° C. and at 37° C. It does not alter the fluid character of the milk, although it produces acid, as is well known by the reddening produced when litmus milk is used as the culture medium." His experiments on cream showed "that cream kept at as high a temperature as 37° C. is not a suitable medium for the growth and multiplication of the typhoid bacillus, but that it is a suitable medium when kept at 20° C. He further found that the typhoid bacillus does not grow and multiply when planted on Cheddar cheese either at 37° C. or at 20° C. (Twenty-ninth report of the medical officer of the Local Government Board for 1899–1900).

In the *Archives de Médecine Expérimentale et d'Anatomie Pathologique*, No. 1, Jan. 7th, 1889, is an account of a research made by M. J. Grancher and M. E. Deschamps on the behaviour of the typhoid bacillus in the soil. Their conclusions are as follows: "1. It does not pass through soil with irrigation water. 2. It is stopped by from 20–40 centimetres of thickness of soil. 3. It retains its life in the midst of all the organisms soil contains, five and a half months after it has been sown. 4. It does not penetrate into healthy vegetables." (*Public Health*, vol. ii., 1889–90.)

A most interesting series of investigations has been made by Dr. Sidney H. C. Martin on the Growth of the Typhoid Bacillus in Soil and his accounts of them will be found in the reports of the medical officer of the Local Government Board for 1896–97 and onwards. He first found that the bacillus when planted in organically polluted soil, "as, for instance, the samples of earth from Chichester," speedily increased and spread abroad, whereas in an unpolluted soil from an uninhabited and cultivated area "it languished and quickly died out" under like conditions of temperature and moisture. It was then determined to test in unsterilised soil of both classes the ability of the typhoid bacillus to contend with the other microbes already present in such soil and Dr. Houston was associated with Dr. Martin in this investigation. 21 samples of various soils were examined. In eight of these no bacillus coli was found. In the remaining 13 bacilli with more or less resemblance to the true bacillus coli were found and in four of these the typical bacillus coli itself was present; these four soils, however, were shown to have been polluted with excrement; while the spores of bacillus enteritidis were found in five of the soils and in exceptionally large quantity in two of them which were shown to have been polluted with excrement. Dr. Martin then showed that when the typhoid bacillus was inoculated on a soil containing bacteria belonging to the bacillus coli group it was recoverable after 50 days from this soil at the point at which it had been inoculated. "It had survived in competition with the bacillus coli-like micro-organisms but had not multiplied."

One of Dr. Martin's most important conclusions is "that the soils which are favourable to the growth of the typhoid bacillus are those which have been cultivated, more particularly soils of gardens and the *entourage* of houses. In these soils the bacillus was found to be alive and to have retained its vegetative properties for as long as 456 days; this being found true for sterilised soil which was moistened throughout with water. On drying this soil, even when it had become so dry that it could be made into a fine powder, the typhoid bacillus could still be obtained from it and had retained its vegetative properties, although it grew more slowly than when obtained from the same soil in its moist condition." Again, "In favourable soils in a moist condition the bacillus not only grew at a temperature of 37° C., but it flourished when the soil was exposed to much lower temperatures; for example, the temperature of the laboratory, which varied between 9° and 24° C. and the temperature of an outside shed between 3° and 16° C." On the other hand, virgin soils, sandy or peaty, "are absolutely inimical to the growth of the typhoid bacillus."

Dr. Martin's further investigations were made on natural "unsterilised soils which in the sterilised condition were found favourable to the growth of the bacillus. In not a single instance, however, was the typhoid bacillus regained, although laborious and prolonged experiments were made with this object. The obvious conclusion, therefore, was that under the conditions of the experiments the presence of the bacteria of the soil had either prevented the detection of the bacillus or had inhibited its growth and so led to its ultimate death and disappearance. It must be remembered that the typhoid bacillus does not form spores, so that its continued vitality depends on its power of multiplication and division. There is no resting-stage of this micro-organism as far as is known, and although in sterilised soil the bacillus will retain its viability for a while if the soil be dried at a low temperature to a powder, yet soon afterwards it dies and can never be re-vivified. Placed, therefore, amidst other bacteria under certain conditions of moisture and temperature the bacillus may in unsterilised soils be beaten out of the field by the other bacteria present." Dr. Martin's further experiments brought him to the conclusion that "there is some evidence to show that under the conditions of experiments the disappearance of the bacillus has taken place *pari passu* with an increase in the number of the putrefactive bacteria." In these experiments Dr. Martin has adopted a method of isolating the typhoid bacillus from the other bacilli present in the soil which appears to give more satisfactory results than the methods which have been previously adopted.

In a long and elaborate paper by Dr. Justyn Karlinski, published in the *Archiv für Hygiene*, Band xiii., Heft iii., the author details a number of careful experiments on the behaviour of the typhoid bacillus in earth and he draws the following conclusions:—"1. The longest life-duration of the typhoid bacillus in earth did not exceed in his experiments three months. 2. The life duration of the bacillus buried with typhoid excreta and hence under natural conditions is essentially shorter than bacilli in the blood buried in earth at the same time. 3. In the deeper layers of the earth the typhoid bacilli bid defiance to moisture, to alternations of temperature, and to the activity of other micro-organisms. 4. Exposed to moisture and sunshine on the surface of the ground the bacilli quickly die. 5. Alternating and copious moisture, whether the moisture rises into or falls on to infected earth, essentially shortens the life duration. 6. In layers of earth in which there are the active roots of plants the life duration is very short. 7. The typhoid bacilli may be recognised three months after death in certain conditions of delayed putrefaction and when the specific micro-organisms of putrefaction are denied access." (*Journal of Public Health*, vol. iv., 1891–92.)

Dr. Klein made some experiments, the results of which will be found in the report of the medical officer of the Local Government Board for 1898–99, on the Fate of Pathogenic and other Infective Microbes in the Dead Animal Body. He was unable to find the bacillus typhosus, or the bacillus coli, or the proteus vulgaris or any other aerobic microbe in the bodies of guinea-pigs which had been previously inoculated with those bacilli, buried, and exhumed 30 days or more later. His experiments showed "that the typhoid bacillus is even less resistant than the cholera vibrio. In 20 days after burial, no matter in what form this had taken place, typhoid bacilli could not be recovered from any of the bodies; from a guinea-pig buried in sand they could not be recovered after 14 days." "The German Commission exhumed the animals not earlier than one month after burial, and their examinations of the dead bodies for typhoid bacilli were in all cases negative."

In the *Journal of the Pasteur Institute* for February, 1897, is a paper by M. P. Remlinger and M. G. Schneider of the Val-de-Grâce laboratory on the Ubiquity of the Typhoid Bacillus. The authors attempt to answer the question, "Does the bacillus of typhoid exist in nature outside the sick man and the products which emanate from him?" A series of experiments extending over many months was carried out on various materials, such as the public water-supplies and wells of several towns having epidemics of typhoid, the soil and dust from different localities, the discharges from the digestive tract of persons not affected with typhoid, &c., and a bacillus giving all the principal laboratory reactions of that of typhoid was obtained from all these sources. The following illustrations are of special interest. In 13 samples of soil and dust the bacillus typhosus was found seven times, (*a*) in the refuse from barracks where there were some cases of typhoid; (*b*) in dust from the laboratory floor; (*c*) in the space between the joists of a room in other barracks; (*d*) in four specimens of soil, both superficial and a metre in depth, from the courts and gardens of Val-de-Grâce. These in three instances were pathogenic for animals. In the examination of the fæces of 10 persons treated at the hospital for affections which had nothing in common with typhoid, five reacted like the bacillus typhosus. Thus (*a*) in a case of leukæmia specimens examined at intervals of 15 days gave each time a positive result, (*b*) in one case of acute tuberculosis without intestinal lesions; (*c*) in a case of premonitory dysentery; (*d*) in two cases of chronic malaria. None of these patients had ever had typhoid fever. Of the bacilli from these five cases four were pathogenic for guinea-pigs. In many additional cultures from water, soil, and the intestines, bacilli with every characteristic of bacillus typhosus were found, except that they were not pathogenic for animals and were not agglutinated by the serum from a typhoid patient. In other words they seemed the same species but attenuated as to virulence. After some remarks illustrated by comparisons with the variations of the cholera vibrio, these investigators state: "It is allowable to suppose that facts of a similar kind reproduce themselves in connexion with the bacillus typhosus. The species of the bacillus of Eberth comprehends, perhaps, varieties more or less numerous which do not probably react similarly under the influence of the serum of an animal immunised against a determined variety. The belief in the invariability of type in pathogenic microbes is to-day much weakened by many facts. The question of race, descendants from a common stock but differentiated by unknown vicissitudes, acquires an importance which must not be underrated. Why should not this theory, which is acknowledged to be true for certain pathogenic bacteria, apply to the bacillus typhosus? We incline to think that bacilli not pathogenic and indifferent to the serum test which are encountered in water, soil, &c., are only varieties of the bacillus typhosus; at least, the parentage is evident even if the identity is not absolute. This diversity of fundamental type will perhaps serve to explain the variable forms of typhoid infection which are becoming recognised. If this interpretation of facts is exact the following conclusion will result. The bacillus typhosus is distributed in nature outside the human body; it is found in potable waters, in soil, in the intestines of persons not attacked with typhoid, and without doubt forms a part of the microbic flora of the media which surround us. This idea is not subversive of recognised facts as to the general etiology of typhoid, but rather enables us to conceive and comprehend facts otherwise inexplicable. Daily observations, especially noted in rural places, have set in relief the part played by contagion in the formation and extension of certain epidemic centres; their value remains. Modern researches have demonstrated the prime importance of impure waters in its development and spread; the character of the proof defies all question. But all the cases must originate from contagion or water polluted with the dejections of typhoid patients. Many times it breaks out in patients or groups worn out with fatigue, overwork, or privations, or after eating various foods, without its being possible to trace the origin of the contagion or the use of a badly polluted water. The facts conform more easily with the idea of the widespread presence of the bacillus typhosus, which accounts for its dispersion in surrounding media and its presence eventually in our natural cavities. A water reputed pure may carry it. Thus introduced into the organism it will live there unoffensive till some depressing circumstance, a fortuitous assistance, perhaps the result of some associated microbe, will open to it a career of action."

Dr. John Robertson, the medical officer of health of Sheffield, made a number of experiments with soil "out-of-doors." The results of these experiments "prove that the typhoid organism is capable of growing very rapidly in certain soils and that apparently under certain conditions the organisms can survive from one summer to another. The rains of spring and autumn or the frost and snows of winter do not kill them off. Sunlight has a most powerful bactericidal influence on the typhoid organism." But this action is limited strictly to the organisms actually on the surface, a layer of soil one-sixteenth of an inch in thickness protecting them. "Cultures of the typhoid organism planted at a depth of 18 inches grew to the surface; so also patches inoculated on the surface showed that at least the organism could grow downwards to a depth of three inches." (*British Medical Journal*, Jan. 8th, 1898.)

According to Liebermeister "the curves representing the frequency of typhoid correspond to the curves of average temperature, only with this difference—the different points of the typhoid curve follow those of the temperature curve by an interval of some months," and he suggests that it takes two or three months for the changes of temperature to penetrate to the breeding places of the typhoid germs. (Ziemssen's Cyclopædia, vol. i., p. 65.)

The present war in South Africa has lent additional interest to the question of typhoid fever in armies and the ways in which it spreads under the circumstances of camp life. In an article on Typhoid Fever in Armies in the Field, by Surgeon-Major Vincent, professor agrégé at Val-de-Grace, Paris, he states that "the predisposing causes were the average age of the soldier; the time of year chosen for military operations, summer or autumn; imperfect feeding and the digestive troubles which resulted therefrom; the inevitable deficiencies as to hygienic conditions as regards both the soldier's body and his clothes; a hot climate, as is the case in colonial wars; the shutting up of troops in camps or besieged towns; a very prolonged war and the demoralisation of an army when conquered. The immediate cause was the ubiquitous bacillus typhosus. This bacillus was able to live in a latent condition in the digestive tract and thence under favourable conditions to multiply itself and give rise to the appearance of a spontaneous epidemic." (THE LANCET, August 11th, 1900, p. 437.)

Some information on the matter is to be derived from the report of Dr. G. Pratt Yule on the camps in the Orange River Colony, published in the *Times* of Dec. 16th, 1900, the most important sentence in which from our point of view is the following. After referring to the fouling of the ground round the tent doors by urine and slops, he says: "Practices such as these have undoubtedly proved the source of a large proportion of the typhoid cases, and these will certainly greatly increase during the coming summer and autumn. In this particular it is important to remember that urine of convalescent typhoid fever patients often contains a pure culture of the typhoid germ which by methods of disposal like the above becomes blown about in the dust of the camps. I am of opinion that the typhoid infection of the camps is principally air-borne."

In the *British Medical Journal* of Nov. 10th, 1900, is an article on an outbreak of typhoid fever at Quetta, India. At this place the water-supply is derived from the hills and is above suspicion. There was, as usual, freedom from typhoid fever up to May but from May 2nd to 13th there were dust-storms with sore-throat and tonsillitis, followed by an outbreak of typhoid fever, some of the cases commencing with sore-throats. The night-soil was placed in pits to the north-west, from which the prevailing wind blew, and in the dry air the deposited matters were dried and blown about as dust. Those companies suffered most who were nearest to the filth-pits; the air from the quarter where the filth-pits were contained "large numbers of germs that are invariably present in fæcal matter and not in pure air, although the enteric bacillus itself was not isolated." It appears from a subsequent article on Sept. 14th, 1901, that "the outbreak ceased on removal of this source of infection." It is also stated that in Jhansi, Nasirabad, Mhow, and Rawal Pindi typhoid fever prevails during the dry season and the dust-storms, and that, on the other hand, Roorkee has very little typhoid fever and is comparatively free from dust.

Dr. H. E. Leigh Canney has published an interesting paper on Typhoid, the Destroyer of Armies, and its Abolition. He holds the view that nearly all the cases of the disease on service are water-borne and in order to prevent it he propounds a scheme for boiling the whole of the water used and suggests the formation of a Royal Water Corps to be devoted to the work of supplying sterilised water, boiling the milk, and "the disinfection of all salads after they have been washed in ordinary water," the watchword of the water corps on a campaign to be "boiled water or nothing." These suggestions met with considerable support at the meeting of the Royal United Service Institution, where the paper was read. Sir William Broadbent, the chairman, pointed out that "whatever importance might attach to dust and flies they were subsidiary to the infection by water. With regard to the efficiency of the method proposed by Dr. Canney, Sir William Broadbent thought that if it could be secured that no soldier drank anything but boiled water they would get the upper hand entirely of typhoid. The whole question turned upon the practicability of the scheme which had been well thought out and was not brought forward in a nebulous condition. Although, of course, they must bear in mind that after a long march or after the excitement and exertions of a fight a soldier could not be prevented from drinking the first water he came across, yet if he started with his bottle full of pure water and the water-carts contained nothing but pure water, whilst only pure water was drunk in the camps, an enormous gain would have been secured." Major R. H. Firth, the professor of military hygiene at Netley, expressed great sympathy with the proposed scheme. He considered that sanitary officers should undergo a special training and they must be supplied with properly instructed men to carry out the work. Dr. J. W. Washbourn insisted that the disease was also conveyed by flies and dust and thought that it was not difficult to provide for a proper disposal of excreta and so to prevent much of the distribution of the poison of the disease by the agencies just mentioned.

A discussion on the Recent Epidemic of Typhoid Fever in South Africa was opened at the Clinical Society of London by Dr. Howard H. Tooth and reported in THE LANCET of March 16th, 1901, pp. 771, 786. He is of opinion that the disease is spread in South Africa not merely by polluted water but also by dust and flies, and he says of the flies that "they naturally infest persons who are ill but seem to be peculiarly attracted to enteric fever patients, hanging in loathsome groups around their mouths and feeding-vessels. They were all over our food, and the roofs of our tents were at times black with them. It is not unreasonable to look upon flies as a very possible agency in spreading the disease not only abroad but at home." He also points out "that with the first appearance of the frost enteric fever almost entirely disappears ...... it seems hardly credible that the almost sudden cessation of an epidemic can be due to the effect of cold upon the enteric fever bacilli only. But there can be no doubt in the mind of anybody who has been living on the open veldt, as we have for three or four months, that the flies are extremely sensitive to the change of temperature and that the cold nights kill them off rapidly. On consideration of these points it is surely justifiable to assign an important share to flies in the spreading of infection."

In the *British Medical Journal* of Feb. 15th, 1902, is a paper by Lieutenant-Colonel R. H. Quill, R.A.M.C., senior medical officer, Ceylon, on Air-borne Typhoid Fever. He maintains that the disease is frequently air-borne and gives his experience of it at the camp of Diyatalawa in the hills of Ceylon, which was formed in August, 1900, for the Boer prisoners of war. There occurred at this camp an outbreak of typhoid fever which was certainly not due to the water or milk, the water-supply and filtration arrangements having been changed in no way since the cessation of the epidemic among the prisoners, and there have been no cases of typhoid fever since 1900. No uncooked food or vegetables were used in the camp. All men leaving the camp for purposes of duty or pleasure were obliged to take with them a water-bottle filled with filtered water. The aerated waters used in the camp were identical with those used at the sanatorium where there was no typhoid fever. Lieutenant-Colonel Quill was driven to the conclusion that the affection was air-borne, being derived from the adjoining camp for prisoners of war, where at the time an epidemic of typhoid fever was raging. After giving his reasons for that opinion he submits that he has shown "(1) that all water avenues through which typhoid fever could have been conveyed to the military camp at Diyatalawa were efficiently guarded and that therefore a water-borne origin must be abandoned; and (2) that the affection was air-borne, resulting from emanations from specifically infected latrines, infected dust, or bacilli-laden flies."

Dr. A. Elliot and Dr. Washbourn contributed a paper on Typhoid Fever in South Africa to THE LANCET of Jan. 18th, 1902, p. 139. They conclude "that the type of typhoid fever met with in South Africa does not differ in any essential respects from that met with in England and America. The mortality and the incidence of complications are much the same as in the variations which are met with elsewhere; the only complication which appears to be especially prominent is phlebitis which occurred in 5·6 per cent. of our cases. ...... We do not feel that inoculation has any marked influence either in preventing or in modifying the disease."

I may add that the hitherto published results of anti-typhoid inoculation are so contradictory and, moreover, are based on such small numbers of cases that I do not think any good end would be attained by further alluding to them.

Since then Dr. George Turner, the medical officer of health of the Transvaal, has contributed a paper to the *British Medical Journal* of Feb. 15th, 1902, on Typhoid Fever in South Africa, its Cause and Prevention. In it he states that he should not advance his opinion on the matter if he "did not feel that the growing tendency to attribute enteric to wind and flies was not becoming a source of danger." He maintains from six years' experience "that the causation of epidemics in South Africa is practically similar to that which gives rise to the majority of cases in England—viz., a polluted water-supply." He states that only on one occasion has he "had any grounds for supposing that dust was concerned in the production of typhoid and on that occasion the dust appeared to have acted through the agency of the water used for drinking." He does not deny absolutely the possibility of typhoid infection by means of wind-borne dust but he says that it is rare. "As a matter of fact, typhoid cases are less frequently met with just at the period at which *dust-storms* prevail and are more numerous when, on account of heavy rain, dust is less troublesome. This, to my mind, is conclusive proof that dust does not exert much injurious influence as regards typhoid. As regards flies I can only say that I hold a similar opinion. The possibility of the conveyance of enteric through these pests is undeniable, but in this instance also the supposed cause, the flies, begin to be troublesome long before typhoid prevails and continue to annoy us long after it has subsided. If the flies were really important agents in the spread of typhoid fever one would expect that even if the disease did not commence to prevail soon after these nuisances commenced to be numerous, ... because it is conceivable that at the time typhoid-infected stools would be rare, yet when once typhoid became common the flies should carry on the infection which should continue as long as, or longer than, the flies continue." Finally, he strongly maintains that "typhoid in South Africa is almost entirely due to polluted water." He admits that filters were sent out with the troops but states that they were not generally used; while, on the other hand, "where the commanding officer had a 'fad about water' the case incidence of typhoid was insignificant." To show that he does not underrate the difficulty of supplying an army with water when on the march he adds: "My private opinion is that if the army had been supplied with the best sanitary expert advice on the march from Paardeberg to Bloemfontein one of two things would have resulted, either the army would never have reached Bloemfontein or it would, as it did, have suffered from fever; one or other of these results was inevitable." The report of the Commission sent to South Africa, consisting of Professor J. Lane Notter, Professor W. J. R. Simpson, and Lieutenant-Colonel Bruce, has not yet been published, so that unfortunately I cannot avail myself of the information contained in it for the purpose of this lecture. I have, however, Professor Lane Notter's permission to state as his own personal opinion that he considers "that while water was a very frequent cause of typhoid fever among the troops it could not, I think, be said to be the *only* cause of it. Others were the aggregation of men on limited areas—density of population—without any of the usual methods of drainage and the disposal of excreta and refuse which exist where numbers are usually congregated together in towns and villages in civil life; this state of things is always present in standing camps; the transference, too, of the contagion by flies, which constitute a real danger unless food is properly stored and kept from them, especially where trench latrines are used. The soil, too, is an important factor; the ground seems wanting in nitrifying organisms, the result being that animal refuse remains long without undergoing that process of disintegration and oxidation that is usual in this country. Perhaps this is due to the absence of lime or like base, for lime is seldom found in large tracts of the Orange River Colony and Transvaal."

I originally intended the subject of these lectures to be merely the "Etiology of Typhoid Fever," and this would have been quite sufficient, but I afterwards thought that it would add to their interest if I showed how the mortality from this disease has been diminished in this and in some other countries by suitable methods of prevention. The methods of prevention themselves are those which apply to any infectious disease and have been described so frequently that there is no need for any further account of them, the only peculiarity in the case of typhoid fever being that less attention need, as a rule, be paid to the methods of preventing direct infection, whilst the greatest attention should be given to the prevention of indirect infection by the channels which have been already described in these lectures. As the disease is no doubt chiefly conveyed by drinking-water it is of the highest importance that this water should not be contaminated with the typhoid poison, or, as Sir John Simon puts it, "It ought to be an absolute condition for a public water-supply that it should be uncontaminable by drainage." Suitable precautions, too, must be taken to prevent other foods, such as milk, oysters, &c., from becoming contaminated. The soil under houses and the air in and around them must be kept pure by the adoption of methods for the removal of excreta from the vicinity of habitations speedily and continuously. The late Sir George Buchanan showed us that the death-rate from typhoid fever was especially lowered in towns where refuse matters were removed most quickly. Among these methods for the prevention of the contamination of the soil and the air are the provision of water-tight house drains, their disconnexion from the public sewers or cesspools, their proper ventilation, and the provision of sanitary appliances and pipes which insure the speedy removal of the foul matters from the houses and prevent the escape into them of any foul air from the drains or sewers. All these matters have been so thoroughly discussed by me in other public lectures that it is quite unnecessary for me further to enlarge on them here.

There appear to be differences of opinion with regard to the disinfection of typhoid excreta; some advocate mixing them with sawdust or other absorbent material and burning them, whilst others are in favour of boiling them. On this subject I may quote Lieutenant-Colonel G. H. Younge, R.A.M.C., who wrote in the *British Medical Journal* of Jan. 18th, 1902: "When in India I tried the process of incineration of enteric excretions mixed with sawdust, but the attempt had to be discontinued as it was found impossible completely to burn the wet sawdust in any incinerator that could be extemporised. On the whole, therefore, I have a decided preference for sterilisation by boiling, as it is quite as effective, less expensive, and more rapid and convenient than incineration." This seems to me to be unanswerable and it is, in fact, obvious that the simplest and quickest way to disinfect liquid excreta must be to boil them.

In May, 1899, Dr. Saltet, professor of hygiene in the University of Amsterdam, read an important paper before the Epidemiological Society on a Study of Enteric Fever in the Netherlands during the period 1875 to 1894. He stated that "during the last decade the number of deaths from typhoid fever has been, generally speaking, on the decrease" and this to a greater extent than the decline in the general death-rate, for while he shows that the general death-rate in the Netherlands declined in the period under review from 23·3 per 1000 living during the quinquennium 1875 to 1879 to 20·0 during the quinquennium 1890–94, or an improvement of 14 per cent., that from continued fevers has declined from 60 per 100,000 to 22, or an improvement of 63 per cent., thus showing "that typhoid fever as a preventable disease *par excellence* has yielded more favourably to the improved condition of the times than other diseases." He then discusses the influence of density of population and comes to the conclusion that "the favourable factors of town life appear thus to outweigh the unfavourable conditions due to density of population." With regard to drinking-water he arrives at the interesting and unexpected conclusion that the death-rate from continued fevers is higher in communes supplied with water from the sandhills than in those with a river-supply, although it has decreased considerably in both; thus in those with the water-supply from the sandhills the death-rate from continued fevers was 60 per 100,000 in the first quinquennium and fell to 19 in the fourth quinquennium, whereas that in communes with the river-supply was 32 in the first quinquennium and fell to 15 in the fourth. Professor Saltet's explanation of this anomalous state of affairs is that "in communes on rivers a sufficient quantity of fresh water is always to be obtained independent of water systems. A number of communes with the ground-water system were, however, frequently suffering from a want of water. Now want of water means want of cleanliness, and it is not at all unlikely that *and* a better quality *and* a more adequate quantity of the drinking-water supply as well as the more liberal use of it have greatly assisted in bringing down the death-rate from fevers. The striking fact remains, however, that in communes with the ground-water system the death-rate from general causes is lower, whilst the mortality due to continued fevers is higher than in the river-water communes. This phenomenon impresses us even more forcibly if we consider that Asiatic cholera, a disease especially propagated by drinking-water, has in the Netherlands played the greatest havoc along the course of the rivers." This would make it seem probable that the increased amount of typhoid fever in communes with a water-supply from the sandhills was due to some other cause than the water, or else that the sources of water-supply are liable to surface contamination.

From a paper on Enteric Fever Mortality in Copenhagen by Dr. N. P. Schierbeck I find that there has been no important outbreak of typhoid fever there since 1857, when the mortality from it there reached 175 per 100,000 persons living; after that there were, as is usual, a few years of low mortality. It then rose to 77 in 1864 and has since steadily gone down until it only averaged 9·4 per annum during the quinquennium 1891–95 and 7·3 during the three years 1896–98. "The central water-supply was commenced in 1854 and completed for the whole town in 1859, when such water was first made use of. The general sewerage system commenced in 1859." The author is nevertheless of opinion that the statistics do not show that the diminution of the death-rate is due to those sanitary improvements, as that diminution began long before those improvements were carried out, but it must be remembered that the previous diminution was not a steady one, as the death-rate from typhoid fever suddenly went up to 175 in 1857, as before stated. (Transactions of the Epidemiological Society, vol. xx., new series, 1900–01.)

In the same volume is an interesting account of the "Effect of Sewerage and Water-supply on the Behaviour of Enteric Fever in Buenos Ayres" by Dr. James T. R. Davison. The typhoid fever mortality was at its highest, 106 per 100,000 inhabitants, in 1890, after which year there was a large and continuous increase in the number of houses supplied with water and connected with the sewers; this was accompanied by a steady decline of the typhoid fever mortality to 14 per 100,000 persons living in 1899.

In preparing Tables III. to VI. and the Chart following, I have been able to include the statistics for 1900 and so to make the tables complete to the end of the last century, owing to the courtesy of my friend Dr. J. F. W. Tatham, chief of the Statistical Department of the General Register Office. Table III. shows the remarkable diminution in the general death-rate of London during the last half of the last century. It will be seen from it that the average general death-rate from 1851 to 1870 was 24·1 per 1000 per annum and that it had gone down to 18·8 in the quinquennium 1896 to 1900; the dates at which the important Acts relating to the public health were passed are shown in the table.

TABLE III.—*London.*

Years.	Average death-rates per 1000 per annum.
1851–1870	24·1
Nuisance Removal Act, 1855, Sanitary Act, 1866.	
1871–1890	22·5
Public Health Act, London, 1891.	
1891–1895	20·2
1896–1900	18·8

In Table IV. the corresponding figures are shown with regard to the general death-rate in England and Wales. The average from 1849 to 1875 was 22·4 per 1000 per annum. The Public Health Act was passed in 1875 and after that the table shows a steady diminution of the death-rate until in the quinquennium 1896 to 1900 it was only 17·6.

TABLE IV.—*England and Wales.*

Years.	Average death-rates per 1000 per annum.
1849–1875	22·4
Public Health Act, 1875.	
1876–1880	20·8
1881–1885	19·4
1886–1890	18·9
1891–1895	18·7
1896–1900	17·6

Dr. Bulstrode prepared a most interesting chart and maps showing the annual death-rate from typhoid and continued fevers per 100,000 living in the counties of England and in North and South Wales during each of the decades 1871–80 and 1881–90. They show "that whilst enteric fever has been undergoing enormous diminution in this country, the areas of both its maximum and minimum incidence have remained practically the same during the 20 years 1871 to 1890, which have witnessed such great improvements in the sanitary circumstances of our towns and villages. The chart shows, amongst other things, that whereas this (typhoid and continued) fever death-rate in England and Wales was 43 per 100,000 living during the decennium 1871 to 1880, it had fallen to nearly half—viz., 22 per 100,000—during the decennium 1881 to 1890." (Sir R. Thorne, twenty-sixth report of the medical officer of the Local Government Board, 1896–97.)

TABLE V.—*Average Annual Death-rates from continued Fevers and Diarrhœa per 1,000,000 Persons living in England and Wales.*

Years.	Continued fevers (chiefly typhoid).	Diarrhœa.
1861–70	885	1076
1871–80	482	935
1881–90	235	674
1891–95	185	630
1896–1900	180	788

TABLE VI.—*Average Annual Rates of Mortality from Typhoid Fever per 1,000,000 Persons living in each Quinquennium from 1871 to 1900.*

—	1871–75.	1876–80.	1881–85.	1886–90.	1891–95.	1896–1900.
In England and Wales	354	278	218	180	176	176
London	256	234	226	150	136	148

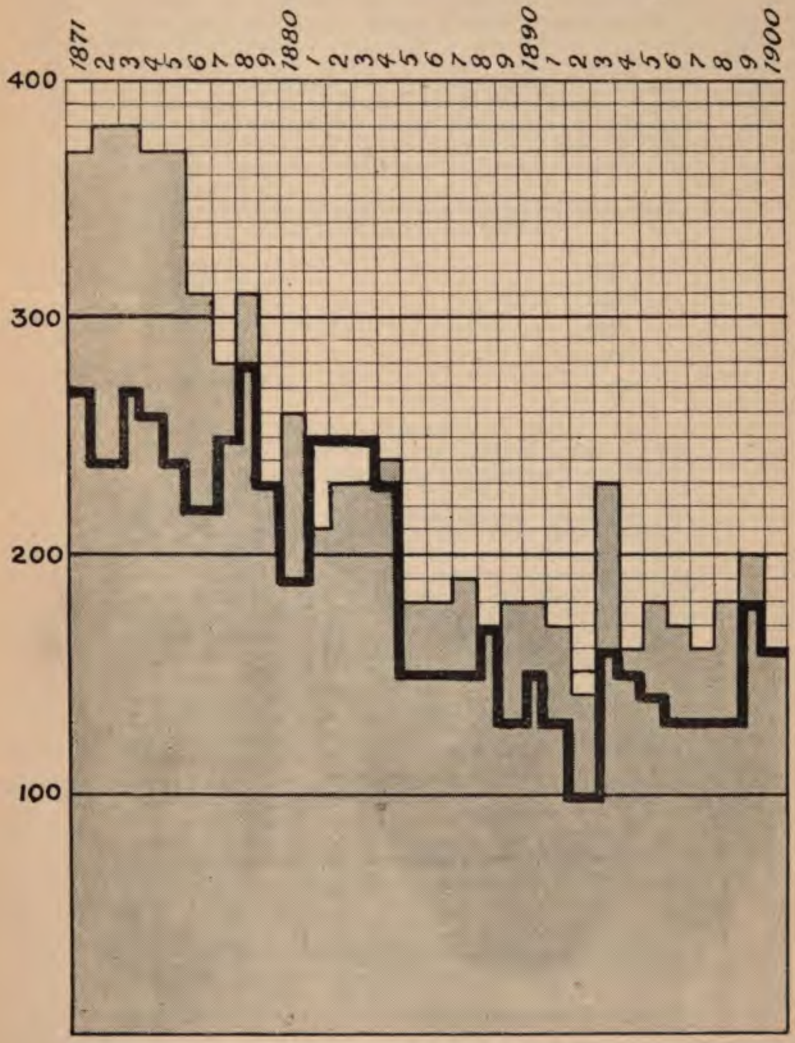
Table V. shows that the rate of mortality in England and Wales for continued fevers (chiefly typhoid) has been reduced from 885 per 1,000,000 persons in 1861–70 to 180 in 1896–1900 and for diarrhœa from 1076 in 1861–70 to 630 in 1891–95, but that the latter rose again to 788 in 1896–1900; and Table VI. shows the steady diminution of the death-rate from typhoid fever alone during each quinquennium from 1871 to 1895 both in England and Wales and in London. It will be noticed that during the last quinquennium (1896–1900) the death-rate from this disease was the same in England and Wales as in the previous quinquennium (1891–95), thus showing no diminution, while in London there was actually an increase in 1896–1900, when the average rate was 148 per 1,000,000 persons, over that in 1891–95, when it was 136. This, as well as the increase in the diarrhœa rate, was due to an unusual prevalence of both these diseases in the years 1899 and 1900.

I have prepared the following chart showing the annual

TYPHOID FEVER CHART.

Showing the Annual Rate of Mortality per Million Persons living from 1871 to 1900.

In London ▭ ; in England and Wales ▨



rate of mortality from typhoid fever (not including simple continued fever) per million persons living in England and Wales and in London from 1871 to 1900, which demonstrates in a graphical manner the remarkable diminution of the death-rate from this disease in England and Wales since 1875, and in London since 1883. It will be noticed that the only years in which the typhoid death-rate in London was higher than that in the country generally were the three years 1881–82–83.

I have already referred to the remarkable diminution of the death-rate from typhoid fever at Munich owing to the improvements carried out under the advice of the late Professor Pettenkofer, a diminution which is even far more remarkable than the diminution in London and in this country generally.

The diminution at Munich was, in fact (in the mean annual mortality per million inhabitants), as follows:—

1851–60	2024
1861–70	1478
1871–80	1167
1881–90	160
1891–1900	52*

From a paper on the "Diminution of Typhoid Fever in Paris," published in the *Revue Municipale* of Dec. 29th, 1900, I find that the death-rate from that disease per 1,000,000 persons living in that city has diminished in a very notable manner, as shown by the following figures. In 1882 it was 1430; from 1883 to 1888 it was 581; from 1889 to 1894 it was 293; and from 1895 to 1900 it was 172. And this in spite of a recrudescence in 1899 and 1900, which was brought into prominent notice on account of the great Exhibition held in Paris in 1900, but which was shared by London and England generally (see chart), and would not have been specially noticed had it not been for the Exhibition.

I hope that these lectures may be of some permanent use, especially as a concise summary of reports of outbreaks of typhoid fever scattered throughout public health literature.

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* This figure has been kindly supplied to me by Professor Halm, of Munich.

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